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PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1874.

BOSTON:
PRESS OF A. A. KINGMAN.
1875.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

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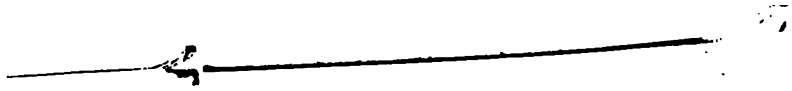

PRESIDENT'S REPORT.

To the Corporation of the Institute:—

Your attention is respectfully asked to the report of the Secretary, and accompanying documents.

The aggregate attendance for the year was 310, a decrease of 65 from the previous year. This decrease was probably due in great part to three obvious causes: (1), the financial crisis which came upon us so suddenly at the beginning of our year, and almost entirely cut off the usual accession of special and advanced students, who join the school after the opening; (2), the increase of the fees from $150 to $200 per annum, which now first took effect; and (3), the increase in the requisites for admission, the elements of French and solid geometry having been added to the requirements of the preceding year. And while these additional requirements, especially the French, were poorly met, and not rigorously enforced in the admission, it is still certain that they influenced the result. The second cause named is known to have changed the intention of some; but it is very probable that the first cause, and which is still operating, was the most potent of all.

It is well known that the success of the previous year was marred by the crowded state of our building. The size of the lower classes made a division into four sections neces-

sary for the proper instruction in some subjects, which made an additional number of lecture and recitation rooms desirable; and in these respects but little relief has been experienced during the past year. Some relief has been afforded by professors using their private rooms more freely for small classes in their own departments; but I am obliged to again ask your earnest attention to our want of room for the proper development of several departments of the school. Nothing more can be done in our present building for perfecting and expanding the work already entered upon; and particularly in the higher departments of instruction upon which, finally, the real rank of our school must rest. No matter how good the instruction involved in our courses may be, nor how perfect the appliances, we shall bar the way to all high aims and results, if we do not in all possible ways encourage a spirit of investigation, and furnish the amplest opportunities for the most advanced instruction, and particularly for scientific research, the most powerful stimulant for both teacher and taught. It is evident that the proper buildings and equipments cannot be had without a large expenditure, and after they are obtained, cannot be maintained without a large current expense; still, if we would attract the highest grade of students, and especially if we would do all in our power to give the proper rank to industrial education, and thus aid, through research in connection with the higher instruction, and through the thorough training of our graduates, in properly developing the wonderful resources of our country, these expenditures must be met. I hope to be pardoned, if I seem too earnest in again pressing this subject upon your attention; but it cannot be, if the facts in the case were fully known by the public, that there would not be a hearty and generous response. The erection of our proposed Chemical Laboratory building, for which the State has already generously given us a site, would give the needed relief, and would probably be all we should require in the way of buildings for some years to come.

Professor Charles H. Wing, who has charge of the department of Analytical and Organic Chemistry, during the temporary absence of Professor Crafts, says that "the room at the disposal of the department is not sufficient for instruction in Analytical Chemistry, many processes must be omitted for want of suitable arrangements for conducting them with safety, and the Professor has viewed with considerable apprehension certain operations, too important to be omitted, involving, for want of a proper room, some danger to the student and also to the building. But Analysis is the mechanical portion of Chemistry and were instruction to cease there, the student would, on graduating, have neither a knowledge of applied chemistry, nor any idea even of the scientific methods of modern chemists, would only be qualified to do the drudgery, to be the 'hewer of wood and the drawer of water' to the chemist proper. The instruction should go farther than this; and the time now allotted in the revised course for laboratory work and the zeal displayed by the students now in this department will, in the opinion of the writer, render it possible to complete the necessary analytical work during the Third Year, leaving the remaining year to be devoted to the study of practical and scientific chemistry. Omitting any discussion of the wants of the department of applied chemistry, if the erection of the new Chemical Laboratory is to be delayed, there is an almost imperative demand for a building of one story, practically fire-proof, affording to the department of analytical and organic chemistry additional room say 30 x 50 feet, more if practicable, less if needs be, but at all events some room properly fitted for chemical research (and for such operations in analytical chemistry as should not be done in the present laboratories) ready to be occupied at the commencement of the next Collegiate year."

I also ask your attention to the able and interesting statement of Professor Ordway, as an important part of this presentation.

The Courses of Instruction. During the early part of the year much time was devoted to a revision of the courses of instruction. It had become apparent not only that too much was asked of the students in all the courses, but that the amount required in the different ones was quite unequal, as was also the work of the different years in the same course. These difficulties had grown gradually by the addition of new subjects, and also by the desire of each Professor to make his own instruction as complete as possible. A new course in Metallurgy was established for those who found the mathematics of the Course in Mining too difficult, and preferred to devote more time to the chemical side of their profession. To meet the wants of the increasing number of students who do not wish to take any of the strictly professional courses, two new ones, one in Physics, and one in Philosophy, were added, and all of them were made distinct from the beginning of the second year, instead of the third, as heretofore. This extension of the strictly professional studies over three full years will prove of great advantage in all the courses. These revised courses went into operation, with few exceptions, at the middle of the year; and although a few more changes will from time to time be found desirable, yet I think that they have substantially solved the difficulties.

Graduation. The question is sometimes asked why so small a proportion of each class graduates, and whether it is not mainly owing to the fact that the courses are too difficult for the average student?

Year.	*Total.*	*Special Students.*	REGULAR STUDENTS.				*No. of Graduates.*	*Percentage.*
			1st Year.	*2d Year.*	*3d Year.*	*4th Year.*		
1864-5	27							
1865-6	72	9	32	31				
1866-7	137	27	64	24	22			
1867-8	167	43	56	37	14	17	14	.518
1868-9	172	63	57	23	22	7	5	.156
1869-0	206	54	68	45	24	15	9	.141
1870-1	224	77	73	36	17	21	17	.304
1871-2	264	84	91	39	33	17	11	.193
1872-3	375	140	115	61	27	32	31	.309
1873-4	310	128	68	59	34	21	16	.219

To answer this question properly we should, in the first place, deduct all special students, as is done in the above table. In the second place, we should also deduct those who take all the studies of the first year without the intention of graduating, which is probably not less than twenty-five per cent. of each entering class; but this allowance has not been made in computing the percentages.

It is undoubtedly true that in the past, inadequate preparation, and an over crowding of the courses, have been efficient causes; but they are no longer controling with the majority of students. It quite frequently happens that a good student takes a strong dislike to a particular subject, and prefers to give up his degree rather than to continue it; and another supposes that by dropping some subject, which he regards as not vital, he will be able to do better in the remaining studies, a supposition which is seldom realized. There is, however, a growing desire on the part of students to graduate, and this, with better preparation for admission, and a better adjustment of our work, will from year to year increase the percentage of graduates in each class.

Theses. This is the first year in which the graduates have presented their theses before the final examination, a change which has been found feasible by the relief afforded in the revised courses during the second half of the fourth year. The general excellence of these theses, and the marked ability of several of them, certainly justify the change. Your attention is called to the abstracts on page 81 of this report.

Preparation for Admission. The High Schools and Academies of the country are, in general, becoming from year to year, more distinctly schools of science and the modern languages, and whatever tends to improve them for the education of the large numbers whose school days end with graduation from them, will the better adapt these schools to fit students for admission to the Institute.

We still need a better preparation for admission to be able to do well in four years what seems desirable: and I take this opportunity to respectfully ask the attention of teachers who may be called upon to prepare students for admission to the Institute, to this subject. We now require "arithmetic (including the metric system of weights and measures), and algebra through equations of the second degree, plane and solid geometry, French grammar through regular and irregular verbs,[1] English grammar and composition, rhetoric, (so much as is included in the first part of Bain's Rhetoric, or its equivalent), and geography. In general, the training given at the best High Schools, Academies, and Classical Schools, will be a suitable preparation for this school."

To make more clear what we still wish to accomplish in the near future, I will also quote from the Catalogue the scheme of our First Year's work.

ALL COURSES. — FIRST YEAR.

			No. of Exercises	Hrs. per week
1	Algebra finished	1st half	45	3
	Plane and Solid Geometry reviewed	2d half	15	3
	Plane and Spherical Trigonometry	2d half	30	3
2	General Chemistry	1st half	60	6
	General Chemistry	2d half	30	2
	Qualitative Analysis	2d half	30	4
3	Structure of the Sentence	1st half	30	2
	Rudiments of Logic	2d half	30	2
4	French		90	3
5	Mechanical Drawing and Elements of Descriptive Geometry and Perspective		90	6
6	Free Hand Drawing		90	3
7	Physiology and Hygiene	2d half	30	2
8	Military Science and Tactics		60	2

We will refer to the subjects in the order given in the scheme. In the mathematics, one-third of the time was spent in a review of what was required for admission. This seemed necessary on account of the inequality in the preparation of

[1] "The amount of French at present required is embraced in Part I. of Otto's Grammar, and the first twenty-five pages of Bôcher's French Reader, or their equivalent."

different students. In the near future we must ask preparation in logarithms, and a few other subjects in algebra, and plane and spherical trigonometry, which will enable us to complete analytic geometry and calculus by the end of the second year, and thus give two full years for analytic mechanics and applications.

We are not likely to ask any preparation in chemistry for some time to come; and yet every secondary school should have a small and inexpensive chemical laboratory in which the elements of the subject should be thoroughly taught. With such aid we could make our general course in chemistry, which ends with the first year, much more complete.

The preparation in English is defective, not perhaps that the student is ignorant of the facts of history and literature, but because he has neither skill, nor ease, nor even accuracy in the use of the language. The remedy is not in the study of history and literature, but in the study of the structure of the language, and a constant application of the few general principles involved, until they become fixed in the memory and in the habit so firmly as never to be forgotten or disused. An occasional exercise in composition is not sufficient. An exercise in writing, in some form or other, should be the one never to be omitted for a single day, until, first, accuracy, and second, facility of expression, have been acquired. A ready use of the language should be made of the greatest aid in the study of all other subjects. What can be clearly expressed must be clearly thought, and no test is of so much value as a written examination.

In French the preparation was better than in the previous year, but upon the whole, not satisfactory. There will be a gain from year to year, and we wish to increase the amount until we can get about twice as much as is now required. This will enable us to complete the general course in this language at the end of our first year, and give proper time in the following years for German.

Free Hand and Mechanical Drawing and the Elements of Descriptive Geometry will soon be well taught in the best schools, and we shall be relieved of most of our first year's work in these subjects.

Believing that these changes will be for the elevation of all the schools involved, we earnestly ask the aid of our fellow teachers in making them a reality.

Discipline. The discipline consists almost entirely in the examinations, all of which are written. The intermediate examinations are those which are held once in about four weeks and occupy one hour, the time of the ordinary exercises. No time is allowed for preparation for these examinations, nor are they allowed to interfere with the current work in any department. The papers are carefully read and marked on a scale of 100. The marks are recorded, and also communicated to the students for their information and guidance. Besides the above, there are the semi-annual and annual examinations. While these are in progress all the exercises of the school are suspended. The position of the student is determined by these examinations. At the semi-annual examinations the record is, passed, passed with conditions, can continue as a special, and dropped. At the annual examinations the record is, passed, passed with conditions, can continue as a special, must repeat the year, and dropped.

Department of Military Science and Tactics. This department has always labored under two serious difficulties; (1), the want of a fixed policy to guide and limit it, and (2), the want of a suitable hall, conveniently situated, in which to give the practical, and by far the most important part of the instruction.

It ought perhaps to have been expected that a subject, entering so little into the main purposes of the school, would be simply tolerated, rather than welcomed, by both teachers and pu-

pils; and that this want of sympathy should have given rise to more care and anxiety than has been demanded by any other department. On this account, also, there has been a wide diversity of opinion as to the exact place it ought to hold in our scheme, and particularly with what detail and rigor the instruction should be given. These have been the vexed questions upon which the Faculty have year after year deliberated; only to find, that no sooner was one settled, than another equally important in the opinion of some one, would arise to take its place. Thus, year by year, had we approximated towards a practical solution of the problem, when, as you are aware, the whole subject was put into the hands of a special committee whose able report adopted June 16, I include for the information and guidance of all concerned. The conclusions were only reached after a careful consideration of all the questions involved, and with the aid of all the experience which the Faculty could offer; and I believe that the opinion entertained by some, that our school was becoming too military in its character has had no foundation in the past, and will have none in the future, other than that which can be fairly drawn from the facts and conclusions of the report. There has been no intention on the part of any one, so far as I know, or even wish, to give the military element undue prominence and importance, much less to convert our school into a military one.

My only desire has been to make it as efficient and valuable as possible, within the limits assigned to it. This has been simply my duty in the matter, and in short the only course which could prevent the department from becoming a demoralization and disgrace to the Institute.

The want of a suitable hall for drill, which could be reached without loss of time, and without discomfort in bad weather, has been a constant source of trouble and embarrassment to the department. This want was carefully considered by the committee and the plan submitted and adopted as the one, which upon the whole, seemed most feasible to meet the pressing

emergency, was carried out during the summer vacation; and I now have the pleasure of reporting that we have an excellent building 155 feet long by 50 feet in width, and one story in height, covered with corrugated iron and a slated roof, containing a light and well ventilated drill-hall, with ample space for gun-racks, wardrobes for uniforms, and boxes for those who use the gymnasium.

Physiology and Hygiene. A large number of our students live on the lines of the railroads leading into Boston, and find it convenient to remain in town all day. They must therefore either dine in the city or bring a lunch, which for the sake of economy is done by the larger number. The result is that these students remain in the building all day, and seldom take the proper exercise, and in bad weather none, except what is got in travelling to and from their rooms, or homes. This want of exercise and a proper midday meal, taken at the right time and under favorable conditions, is having effect upon the health of our students, and is a much more serious matter than hard study. Where the health of one student is injured simply by over study, the health of many is injured by want of exercise, or other preventable causes, while over study is usually the only cause assigned. It is true that each class hears an excellent course of lectures on Physiology and Hygiene, but it is to be feared that too few make a personal application of what is taught them, and thus fail to gain what this instruction is mainly intended to impart. I am deeply impressed with the conviction that a radical change in this department is necessary, and that the laboratory system is quite as important in this as in other departments of the school. To make the instruction of the greatest value to each student it must be applied practically in each case; and while I am not now prepared to advocate a compulsory system of gymnastics, I am satisfied that incalculable good would come from a more personal application of the instruction, with opportunities for

systematic exercise under the direction, not of a mere gymnast, but of a physician who had made this application a matter of special study. If our students lived in dormitories, as at most colleges, or so near each other that their spare time could be spent in out-door athletic sports, the case would be somewhat different; but there is probably hardly another school in the country where the students are so thoroughly scattered, and such exercise had, if at all, at so great disadvantage.

Our only remedy therefore, in addition to what is afforded by the drill to only a portion of our students, is a gymnasium. I take advantage of the delay in the issue of this report to briefly indicate what has been already done in this direction. When the drill-hall was finished we took immediate steps to fit it as a gymnasium. The apparatus which could be best placed against the wall is fixed; but that occupying the central portions of the hall is so arranged, that it can readily be raised a sufficient height from the floor as not to interfere with the drill. By this means the hall has been made equally available for both uses. This gymnasium is open to all the students from early morning till 9 o'clock in the evening. We have also availed ourselves of the opportunity which the drill-hall has afforded us to establish, by way of experiment, a *lunch room*, where professors and students and their friends can get a well-cooked and well-served dinner or lunch, as desired, at a very reasonable cost; so reasonable as to induce those who have depended upon a cold lunch to do so no longer. Dinners, or lunches, are served from 12-30 to 3 P. M., during which time all can be accommodated. Dinners consisting of soup, fish, meat or poultry, dessert, and a cup of tea or coffee, is served for 35 cents, and a lunch at a correspondingly low rate.

In this matter the Institute assumes no responsibility or expense, except that no charge is made for rent or for fuel used in cooking. We fix the prices charged; and the quality of the food, the cooking, and the manner of serving, must be satisfactory to us. In spite of the imperfect conveniences, the ex-

periment thus far has been unexpectedly successful; and if it shall continue equally so in the future, it will be desirable to provide better accommodations, which can readily be done at a very small expense. Then good board can be obtained at from three dollars to three and one-half a week. I trust that those members of the Corporation who have not already done so, will make a personal examination of this matter, and thus be able the better to judge of its importance and bearing upon the welfare of the school.

I cannot close without acknowledging the energy and zeal of Lieut. Zalinski in the erection of the drill-hall, and his valuable service in equipping the gymnasium, and superintending the lunch room experiment.

Lowell School of Industrial Design. In my last report a pretty full account of the establishment of this important department was given, with such indications of success as so short an experiment seemed to justify. Although a good proportion of the students of the First Year returned, it was by no means sure that their zeal and perseverance would not flag before they were at all qualified to enter upon their professional work with a fair prospect of success. But the results of the Second Year have fully realized all reasonable expectations, as I think the facts set forth in Mr. Kastner's report show. In another year some of the students will probably complete the prescribed course and be entitled to the proper diploma, or certificate of proficiency.

The Zoological and Palæontological Laboratory. This laboratory has been fitted up in the building of the Boston Society of Natural History for the joint use of the Society and the Institute. Here Professor Hyatt gives his instruction in Palæontology, and also his course in Comparative Zoology, in the third year, and the laboratory work of the fourth year to students in the course of Natural History. This gives the best

possible opportunity for the convenient and proper use of the valuable collections and library of the Society, under the direction and care of the Society's own Custodian. In this way is the Society aiding to place within reach of all the amplest facilities for study in all departments of Natural History.

Department of Mining Engineering. On the first of January, 1874, after nearly five years of efficient service as Professor of Mining Engineering, Professor Rockwell resigned his professorship to accept the responsible position of Fire Commissioner o the City of Boston. The duties of the Chair were divided between Professors Ordway, Hunt and Richards, and we were particularly fortunate in being able to have the instruction continued without a break by Professor Rockwell's associates in the department. The mining laboratory has been improved during the year by the addition of such machines as were found necessary to carry on the required work.

Department of Architecture. The work in this department is now arranged in two courses; one of four years for regular students, leading to the degree of Bachelor of Science; and the other of two years for special students which includes all the drawing and architectural instruction of the longer course. For admission to this special course no examination is required; the applicant must be sixteen years of age, and if he wishes to take additional studies, must be examined if the subjects require it. This shorter course is arranged for those whose time and means are limited.

Department of Mechanical Engineering. In my last report Professor Whittaker gave the plan of the kind of laboratory which it was thought desirable to build up to aid in the instruction in this department, and also adapted to the solution of any new problems which might arise in relation to steam and power, and such other questions as are involved in their use. I have

now great pleasure in calling your attention to Professor Whittaker's report showing what has been done during the year towards carrying out the proposed plan. This marked and substantial progress is mainly due to the timely aid of Mr. George B. Dixwell, who has not only furnished us with a large part of the means, but what is far more important, has set us a definite problem of the highest scientific as well as practical importance to solve, thus imposing conditions of a very high order, and at the same time aiding us with the knowledge and experience gained by years of study and reflection upon the nature of steam. It is difficult to conceive of a more fortunate combination of circumstances, and at the same time used to better advantage than they have been by Professor Whittaker; and it is my pleasure as well as duty to testify to his zeal and ability in carrying out his plans, regardless of all personal sacrifices. The interest of the students of this department in this laboratory has been so marked, and their aid so valuable as to be entitled to special mention and commendation. We still need, to make this laboratory as complete as possible with the space at our disposal, a few of the most approved machine tools, and whatever else may be necessary to furnish a small shop.

The Society of Arts. This important department merits more attention from the Corporation. The meetings for the year have been fairly well attended, and the communications have been of more than common interest and value. The Secretary has given a fuller report than usual, which is an improvement over the very condensed abstracts of previous years. The value of the report would be increased by a still more liberal summary of the records; but this cannot take the place of a monthly bulletin in which a full record of the meetings can be given. This form of publication, more full and frequent than the annual report, and more permanent and convenient than any newspaper report, however good, can be, would increase the interest in the meetings and improve the value of the com-

munications, because much more care would be taken in their preparation.

Again, the Society needs better facilities for exhibiting in operation the various kinds of machinery, subjects of interest and instruction to all. The extension of our laboratories will in time furnish to the members better opportunities for experimental researches than we can now offer, and add very much to its effectiveness as a Society of the Industrial Arts. Your attention is respectfully asked to these considerations.

Department of Civil and Topographical Engineering. The instruction in this department has been continued substantially as in past years, except that more attention has been given to the practical details of bridge construction. In this subject, as also in hydraulics, and particularly in water-supply and drainage, there is need of fuller instruction in the practice, that the graduates in the department may be as well qualified to enter upon these subjects as they are upon railroad construction. The subjects of water-supply and drainage are rapidly growing into prime importance, and it is extremely desirable that the students should have the advantage of the widest and best experience which can be obtained. If the instruction as now given could be supplemented by courses of not more than thirty lectures each, on bridge construction, and water-supply and drainage, to be given on alternate years to students of the third and fourth years, by an engineer of large experience, and illustrated by some of the excellent examples to be found in the vicinity of Boston, nothing more would be desired. This addition would not overburden the course, nor add largely to the expense of the department; nor would it be difficult to find one among the many able and experienced engineers of this city, who would undertake to give this instruction.

On May 30, 1864, the Committee on Instruction reported through its chairman, President Rogers, the "Scope and Plan of the School of Industrial Science of the Institute," in which

it was proposed to establish laboratories for instruction and research in several of the leading departments. In order that we may readily compare what we have been able to accomplish during the past ten years towards realizing the proposed plans, I quote from the report the part relating to this subject.

"The laboratory arrangements of the school are designed, when complete, to embrace the following departments: —

1. A Laboratory of PHYSICS AND MECHANICS.
2. A Laboratory of GENERAL CHEMICAL ANALYSIS AND MANIPULATION.
3. A Laboratory for METALLURGY AND MINING.
4. A Laboratory for INDUSTRIAL CHEMISTRY.

While intended primarily for the instruction of the students, these laboratories will be used for the prosecution of experiments and investigations on subjects referred to them by the Committee of the Museum or the several Committees of Arts, including the examination and testing of new machines and processes, and the conducting of original researches in the different departments of applied science; and in these critical studies and experiments the advanced students may, when expedient, be permitted to assist.

Laboratory of Physics and Mechanics.

In this laboratory, it is proposed to provide implements and apparatus with which the student may be exercised in a variety of mechanical and physical processes and experiments. Thus he may learn practically the methods of estimating motors and machines by the dynamometer, of experimenting on the flow of water and air or other gases, and of testing the strength of the materials used in construction. He may become familiar with the adjustments and applications of the microscope; be practised in observing with the barometer, thermometer, and hygrometer; and, in a room fitted up for photometry, may learn the mode of measuring the light produced by gas and other sources

of illumination, and the value of different kinds of burners, lamps, and their appendages.

Laboratory for General Chemical Analysis.

In this laboratory, provision will be made for a complete and comprehensive course of instruction in qualitative and quantitative analysis,—embracing organic as well as inorganic substances,—and blending lectures with the systematic practice of the laboratory.

Students proposing to take the course will be expected either to have passed through the first two years' teachings of the Institute, or to be possessed of such knowledge of general chemistry and physics as these preliminary studies are intended to impart.

Besides this general and extended course, it is proposed to have certain partial courses, in which students having a special object in view may obtain instruction of a specific kind, without going through the entire range of laboratory training. Such would be,—

1. Exercises in Organic Analysis.
2. Exercises in Blowpipe Testing.
3. Household and Commercial Analyses, including the Testing of Waters, Detection of Adulterations in Food, &c., Alkalimetry, Acidimetry.
4. Chemical Toxicology, Detection of Arsenic and other Poisons.

Laboratory for Mining and Metallurgy.

Connected with the general laboratory, but forming a distinct department, will be a laboratory of mining and metallurgy, designed for special instruction in whatever relates to practical mineralogy, the chemical valuation of ores, and the operations of smelting and other processes for the separation and refining of metals.

In this department, students already trained to some extent in analytical processes will be exercised in the examination and discrimination of rocks and minerals by mechanical and chemi-

cal tests, including a course of practice with the blow-pipe; and will be taught the several methods of assaying the ores and alloys of copper, iron, lead, silver, and other useful metals, as well by the dry as the wet method; of analyzing the fluxes used in the smelting furnace, and the slags resulting from the blast; and of determining the combustible value of the mineral or other fuel with which furnaces are supplied.

In aid of these instructions, the student will have the opportunity of studying the models of mines, and of mining and metallurgical implements and machinery and the collections of rocks, fossils, minerals, and ores, with their manufactured products, provided and arranged specially to facilitate his studies in this department.

Laboratory for Industrial Chemistry.

It is further proposed to connect with the general laboratory a department of industrial chemistry, where students may have an opportunity of becoming practically familiar with the materials, implements, and processes of the more important chemical arts and manufactures.

In this department will be provided a collection of dye-stuffs, mordants, discharges, and other substances used in the operations of dyeing, color printing, and bleaching; together with such apparatus as may be necessary, on a small scale, to exemplify these several processes as in actual use.

Here the student will have access to suites of specimens, embracing the crude materials and products of the glass and pottery, and brick and tile manufactures, the different soaps, soda ash, bleaching salts, acids, saline products, lakes, pigments, inks, cements, tanning substances, and other materials and products of the chemical arts; and will be provided with facilities for studying practically the re-actions and processes connected with their use and manufacture.

Provision will also be made in this laboratory for the practical illustration of the chemical modes of engraving and lithography, and for exhibiting the various methods and

processes of electro-metallurgy as applied to silvering, gilding, and the deposition of copper and brass."

It will be observed that two objects were contemplated in the establishment of these laboratories; first, the instruction of the students as a part of their general education, and second, to afford opportunities for investigation in special subjects, in which competent students might participate, or even conduct the research under proper direction and supervision. Thus far our means and energies have been mainly expended in providing for the instruction, the provision for special investigation being incidental, and limited to such inadequate space and resources as are at our disposal. We are now, however, the better prepared by the experience of the past years, to enter upon this wider field, and can but hope that the near future will provide the means to attain this most desirable end. When this is done we shall be much better prepared than now, in some important particulars, to attract graduates of our own and other institutions to us for advanced and more comprehensive courses of study.

Railroad Fares. The average age of students entering the Institute has gradually increased with the increase in the requirements for admission. On this account the number of those living on the lines of the railroads, and coming within the rule of half fare while under eighteen years of age, has been growing relatively less. I have now the pleasure to report that during the year, at my solicitation, all the roads, with a single exception, have abolished the rule and now carry all our students without reference to age at the reduced rates. For this important reduction in the expense of a large number of our students the thanks of the Corporation of the Institute are due.

In closing this summary of our very satisfactory year's work, I must recognize two important conditions as always largely influencing the amount and quality of the instruction. The

first is found in the fact that so many of our students come to the Institute from choice, with a more or less well defined purpose as to the preparation they desire for the duties of active life, and are not sent by parents or guardians against their wishes. This indicates a maturity of character and a seriousness of purpose, upon which we have found it entirely safe to rely in all our dealings with our students. We grant, that in the above respects they are men, and not boys, and our discipline is shaped in accordance with this fact. We insist upon respectful conduct, and entire honesty in all examinations and other exercises, and the least infraction of these general rules makes it undesirable to continue the student's connection with the school. Instances where such discipline is needed are exceedingly rare, and made so, mainly, by the spirit which prevails among the students in relation to the causes of it.

The other condition is found in the devotion of all the teachers to the interests of the school. That all should conscientiously perform all assumed duties is expected and requires no special remark; but in the building up of laboratories, and best adapting them to the purposes of instruction, particularly in departments where there was little or no experience to guide, there was needed knowledge, and energy, and above all patience and faith. So many of our Professors have commanded success by the devotion of all their time and energies, and in addition, by contributing liberally of their private means, that the fact is worthy of special mention and recognition.

Deeply grateful for the measure of success which has rewarded the labors of the year, I close this report,

J. D. RUNKLE, *President.*

SECRETARY'S REPORT: 1873-74.

There have been during the year eleven meetings of the Society of Arts, at which the average attendance was seventy-five.

Nov. 13, 1873. Mr. Frederic Ransome, of England, read a paper, illustrated by specimens, experiments, and diagrams, on "Discoveries in the Manufacture and Uses of Artificial Stone," with special reference to the process which bears his name.

Of the processes, his was one of the earliest and most successful, he having commenced his experiments more than thirty years ago, with hard silicious sands and cements of various kinds under great pressure. These proving unsatisfactory, he employed with the same sands a concentrated solution of soda or potash in the form of a silicate. With silicate of soda as a liquid, he mixed chloride of calcium in solution, and produced a stone of flinty hardness, which he could mould into any form; the silicate of lime thus formed in the stone is practically indestructible in the air, and the chloride of sodium is removed by washing. With silicate of potash a firm stone is made, disintegrating under the influence of heat, the soda stone being affected by moisture.. The setting takes place quite rapidly, and the insolubility is in proportion to the amount of silica.

The experiments of Mr. Ransome fully proved, in opposition to the statements of chemists, that the silicate of lime thus formed was a permanent stone. It has been subjected to the extremes of heat and cold, with sudden transition from one to the other, to acids, and to various gases, with no effect on its

structure. Being nearly all silica, it is practically indestructible; having no oxidizable constituent, it is unalterable in the air; being impermeable to moisture, it cannot be injured by frost. It may be used for any purposes of construction or architectural ornament that natural stone can be employed for. It has been used for twelve years in Europe, and for some time in Chicago and San Francisco.

His latest form, called *apœnite*, grows stronger with age, may take any color by the use of metallic oxides, and may be made almost anywhere, as the materials are very common, thus saving the expense of transportation.

Prof. T. Sterry Hunt followed in some remarks, showing how this method imitates processes of nature on a grand and beneficent scale.

Prof. Ordway made some further practical statements on the composition and uses of water-glass and hydraulic cement, both involving some of the principles of Mr. Ransome's process.

An automatic Elevator Brake was also exhibited at this meeting.

Dec. 11. Mr. J. P. Putnam exhibited his invention for lighting gas by frictional electricity, by the simple turning of the gas cock, avoiding the danger and the trouble of the use of matches. No perishable material is used, brass and ebonite, or hard rubber, being the principal ones. The apparatus was tested several times before the meeting, and it was as certain in its action as it was simple and durable in its construction.

Mr. Horace McMurtrie read a paper, with illustrations, on "Sectional Boilers," and especially on the form known as the "Wiegand Boiler"; he described also the "Miller or American," and the "Exeter" boilers, — all of cast iron, which is claimed to be the best conductor of heat, and the safest material to guard against destructive explosions. All such boilers are open to the objections of many joints exposed to the direct action of the fire; of unequal expansion and contraction; of insufficient circulation from the divided state of the water; and of inaccessibility for purposes of examination, repairs and clean-

ing; each joint is an element of weakness, and the system of hanging tubes is disapproved by many engineers.

Jan. 8, 1874. Mr. Samuel Batchelder, of Cambridge, presented a dynamometer of his invention, with a detailed description of the same. It is applicable both to steam and water power, for heavy or light machinery, and affords the means for accurate measure of power exerted.

Prof. Whitaker then read a paper on shafting as a means of distributing power, alluding to some of the old-fashioned methods of shafting mills, some deviations from these methods in use, and others contemplated. Without wishing to condemn the prevalent use of light, rapidly-rotating shafting, he stated, that, though this appears to consume much less power than heavier shafting, the difference is far less than is generally believed; the gain, he thought, was more in the use of better materials, more careful workmanship, and more perfect lubrication, than in the increased speed of the lighter shafting.

Jan. 22. Mr. Albert K. Mansfield, of Lowell, made a communication on the "Theory of Turbines," passing in review the four principal methods of converting the power of water in motion into useful effects, viz.: 1, by *impact*; or allowing the water to impinge on planes, or floats in motion, set at right angles, or nearly so, to the direction of the flow; 2, by *pressure*; the water pressing on the floats in motion, but so confined as to move no faster than these; 3, by *reaction*; of the water flowing from orifices against their walls; 4, by *deviation*; of the water from the direction in which it tends to flow, according to the principle that a body resists deviation from straight line motion. The action of water in wheels is often a combination of two or more of these methods. He gave the theoretical formulæ in each of these cases.

Prof. Whitaker drew attention to the indefinite way in which the word *theory* is used, as distinguished from *practice*. The popular, and a very mischievous, belief is that practice is opposed to theory; practice may be opposed to *hypothesis*, which many mistake for *theory*. Theory, in its true sense, means the

whole theory of a scientific problem, all disturbing elements having been considered, and thus is the same as practice. When an incomplete theory is under discussion, its incompleteness should be stated, and then we should hear no more of the supposed, but really non-existent, antagonism between theory and practice.

Feb. 12. Mr. David Renshaw described from a model a new form of sectional boiler, of his invention, which had been in successful operation for several months in Hingham, Mass.

The material is cast iron, and the form that of the reverberatory furnace. This form secures the hottest part in the crown or arch, and by a gradual increase from below upward; the boiler is of a corresponding form, being in its outer portion a true half circle, giving the reverberatory form of furnace and drop flues; all the fire surfaces are directly over the grate, and are very large. The circulation is rapid, and cleaning easy; none of the joints, always a fruitful source of trouble in sectional boilers, come in contact with the direct action of the fire; they are very few, and very accessible. His plan retains the colder, heavier water in the lower portion of the boiler, where it ought to be — a great security against explosion from sudden rise of pressure.

Feb. 26. Mr. Horace McMurtrie read a paper on "Boiler Explosions no Mystery" — being a careful review of the facts presented in the Report of the "Hartford Steam Boiler Insurance Company."

He alluded to the well known causes, of defective materials, faulty construction and form, and especially the ignorance and carelessness of those having charge of boilers. Improper riveting and insufficient bracing, safety valves overweighted or corroded in their seats, inaccurate steam and water gauges, defective setting, inattention to the supply of water, neglect of inspection, were in turn taken up. He gave the record of nearly 12,000 defects discovered in a single year by the inspectors, from the examination of a very small proportion of the boilers in the United States, and of these nearly 2900 were dangerous.

He thought the mystery was that, under the circumstances, more boilers did not explode.

March 12. Mr. J. R. Robinson read a paper, in answer to Mr. McMurtrie, admitting the facts stated, but citing numerous cases which had come under his official investigation, where the explosion of boilers could not be accounted for by any of the conditions above named. He believed that there was a mystery in the causes of these explosions, and that the only safe way was to investigate this mystery, so important for the users of steam.

March 26. Mr. Stephen M. Allen read a paper on "Light and Heat, and their relation to Steam."

Mr. Guthrie made a communication on the Morton Ejector Condenser, explaining its construction by diagrams. This condenser dispenses with the air pump; the exhaust steam escaping from the cylinder is so directed as to unite in a jet with the injection condensing water, by which it is condensed — having first, however, imparted a sufficient velocity to the combined jet, to enable this to issue direct into the atmosphere in a continuous impulsive stream; the contents of the condenser, both water and air, are thus ejected without the use of the pump, and without impairing the vacuum maintained in the condenser.

An interesting discussion took place on various points suggested by this communication.

April 9. Prof. A. Graham Bell occupied the evening in remarks on "Visible Speech," or the "Science of Universal Alphabetics," a system invented in 1864 by his father, Prof. A. Melville Bell.

In this system sounds are represented by symbols indicating the positions of the vocal organs assumed during their production. These may be arranged in a linear series, like letters, forming an alphabet capable of representing the sounds of all languages — a system of universal alphabetics.

He illustrated its application in teaching the deaf to speak. In the deaf the vocal organs are perfect, and the deaf have

hitherto been dumb simply because they cannot hear and imitate sounds, and because the concealed mechanism of speech cannot be seen. By his system the deaf can see how to place the tongue, lips, etc., for the production of every sound, and thus to speak. The system was first introduced in England in 1869, and in America, in Boston, in 1871; it has been attended with remarkable success, and is now extensively used in this country for the education of the deaf and dumb, a class fortunately now not neccessarily dumb because they are deaf.

Its value was demonstrated to the audience by several pupils of his. The system is now adopted by the Boston University.

May 14. Mr. A. C. Cary, of Malden, made a communication on a process, invented by himself, of weaving on a rotary loom. It both knits and weaves at the same time, making a very strong, non-elastic cloth, of any desired width, a yard a minute, and at a very cheap rate. Specimens of this fabric were exhibited.

Mr. E. H. Hewins then read a paper on some of the principal points of difference between the American and European systems of iron bridge building, in which he gave his reasons for preferring the former.

May 28. Mr. Robert B. Forbes read a communication on the best means for preventing collisions at sea, and of strenghtening vessels.

The importance of the so-called Maury lanes, now adopted by the Cunard Company, was dwelt upon. The necessity of the adoption of some such plan has been demonstrated by a series of recent terrible disasters.

He advocated the frequent use of the steam whistle in a fog, sounded so as to indicate the general course of the ship. He dwelt also on the necessity of having ships with double bottoms, without openings between engine room and fire room, or between coal holds and fire room, except in the last by some sort of elevator to carry the coal over the load line into the receiver, near the furnaces.

Mr. C. W. Hinman, a graduate of the Institute, and now "State Inspector of Gas," made a communication on "Gas Analysis."

After giving a history of the apparatus and processes employed by Lavoisier, Bunsen, Regnault, Williamson, and Russell, he explained his own in detail. His process is much simpler than any others in use.

Mr. C. A. Morey, a pupil of the Institute, described the various methods of rendering sounds visible, and gave the results of an extensive series of experiments made by him the past winter with the "Phonautograph" — modified and improved by himself. The curves made by the style set in motion by the vibrations of the membrane of the instrument, were exhibited, highly magnified, by the oxy-hydrogen lamp.

There have been elected during the year eight associate members. Seven associate members have died during the year viz: Messrs. Copeland, Derby, F. H. Jackson, Jewett, Reed, Sweetser, and Thompson; five have resigned, and fourteen have been dropped for non-payment of fees. The list now comprises 297 members.

The attendance at the School of Industrial Science for the year, has been 310; as follows: Resident Graduates, 2; Regular Students of 4th year, 21; of 3d, 34; of 2d, 59; of 1st, 68: Students not Candidates for a Degree and Special Students; 4th year, 13; 3d, 27; 2d, 25; 1st, 35; Students in Practical Design, 26, of whom 15 were females. Of these, as in former years, nearly five-sixths are from Massachusetts, principally from Boston and vicinity; from other New England States, 17; viz: from Maine, 5; New Hampshire, 5; Vermont, 3; Rhode Island, 3; Connecticut 1. From other States there are from New York, 7; Ohio, 8; Pennsylvania and Illinois, each 5; Minnesota and Western Islands, each 3; Indiana, Kentucky and California, each 2; New Jersey, Maryland, Kansas, Missouri, Nebraska, Colorado, British Provinces, Japan, and the Sandwich Islands, one each.

Thirty-eight professors and teachers have been connected

with the school, and several advanced students have rendered assistance in the laboratories, drawing, and surveying. The fees from students have been over $50,000, considerably more than last year.

The School of Design continues to be a successful department of the School, and the report of the teacher in charge will show the artistic and pecuniary value of the work done.

The Lowell Courses this year have been as follows:

Logic: An Examination of the System of J. S. Mill. Eighteen lectures on Monday and Friday evenings, at 7½ o'clock, beginning November 17, by Prof. Howison.

Sound. Eighteen lectures, illustrated by a full series of experiments, on Wednesday and Saturday afternoons, at 3 o'clock, beginning January 7, by Prof. Cross.

Machine Drawing for advanced students. Twenty-four exercises, of two hours each, on Tuesday and Friday evenings, at 7½ o'clock beginning November 18, by Instructor Schubert.

Elementary Descriptive Geometry. Eighteen lectures on Monday and Thursday evenings, at 7½ o'clock, beginning November 17, by Prof. Lanza.

Chemistry: Qualitative Analysis. Twenty-four laboratory exercises on Wednesday and Saturday afternoons, at 2½ o'clock, beginning Feb. 11, by Prof. Nichols.

Architectural History and Design. Eighteen lectures on Wednesday evenings, at 7½ o'clock, beginning December 3, by Prof. Ware.

Elementary German, Eighteen lessons on Monday and Wednesday evenings, at 7½ o'clock, beginning November 17, by Instructor Krauss.

The Corporation have held eleven meetings during the year.

At the meeting of Dec. 10, 1873, the Degree of Bachelor of Science was conferred upon 19 Graduates of the Institute; in the Department of Civil Engineering, 9; of Chemistry, 6; of Geology and Mining Engineering, 2; of Mechanical Engineering, 1; of Architecture, 1.

Profs. Watson and Rockwell have resigned during the year; Prof. Channing Whitaker was appointed in the place of Prof.

Watson, and the work of Prof. Rockwell was divided among Profs. Ordway, Hunt, and Richards.

At the same meeting was received and accepted the gift of a marble bust of the late Albion K. P. Welch, from the executors of the estate.

At the meeting of Feb. 11, 1874, it was voted to establish a Mechanical Laboratory, whenever it could be done without encroaching on the present funds of the Institute.

A valuable gift of 79 volumes of the American Journal of Science and Art (Silliman's), substantially bound, from the commencement to 1860, was made by Thomas G. Appleton, Esq.; also a cannon, the invention of the late Prof. Daniel Treadwell, by Mrs. Treadwell.

At the meeting of Feb. 20, on a proposition of the Boston University, it was voted that the Professors of Physics in the Institute be authorized to receive a class in Physics from the Boston University, for one year, on conditions presented by the Committee on the School.

On April 8, was presented, from Mr. Cummings, a marble bust of Prof. Wm. B. Rogers, with pedestal.

At the meeting of June 16, it was voted to confer the Degree of Bachelor of Science on the following students, who had successfully passed their examinations, and fulfilled the required conditions:

Herbert Barrows	Reading . . .	Dep't of Civil Engin'ing.
Wm. T. Blunt	E. Somerville .	" "
George E. Doane	Middleboro' . .	" "
Joseph S. Emerson . . .	Hawaiian Is. . .	" "
Elliot Holbrook	E. Abington . .	" "
Aechirau Hongma. . . .	Japan	" "
Chas. P. Howard	Hartford, Conn. .	" "
Herbert B. Perkins . . .	Ware	" "
Edward S. Shaw	Cambridge. . .	" "
Arthur W. Sweetser . . .	Cliftondale. . .	" "
George H. Barrus	Reading . . .	Dep't of Mech. Eng'ng.
Willis H. Myrick	Peterboro', N. H.	" "
Frank H. Pond.	Woonsocket, R. I.	" "
Francis H. Silsbee. . . .	Salem	" "

Frank H. Jackson	Brighton . . .	Dep't of Mining Eng'ng,
Wm. B. Dowse	Boston	Dep't of Architecture.
Robert C. Ware	Marblehead . .	Dep't of Sci. and Liter.
Stephen H. Wilder . . .	Cincinnati, O. .	" "
Benj. E. Brewster (1872) .	Boston	Dep't of Mining Eng'ing.
Geo. W. Blodgett (1873) .	Boston	Dep't of Civil Engin'ing.
Sam'l M, Felton, Jr. (1873)	Thurlow, Pa. . .	" "
Frank W. Very (1873) . .	Salem	Dep't of Chemistry.

Subjects of Theses, with abstracts, will be found on p. 81.

The progress of the school in the various departments will be found in the reports of the Professors, and the President.

SAMUEL KNEELAND, *Sec.*

DEPARTMENT OF GENERAL CHEMISTRY.

President Runkle: —

DEAR SIR: — As the changes which have been made during the past year in the Courses of Instruction have involved some changes in the instruction in General Chemistry, it may not be inappropriate briefly to allude to the plan at present pursued.

The method originally adopted for teaching Elementary Chemistry was based upon the ideas, — 1st. That all the regular students of the School should receive a certain amount of instruction in General Chemistry and in Qualitative Analysis. 2d. That some knowledge of the facts and principles of the science should precede the attempt to learn Qualitative Analysis, with which branch of the subject the instruction in some institutions begins. 3d. That the proper method of learning these fundamental facts and principles is by actual work in the laboratory where the student sees and handles for himself, this laboratory work being supplemented by systematic study of the text-book, enforced by familiar lectures or oral explanations. This system has been followed since the laboratory was opened, and there is no reason to feel that any better general plan could be pursued.

The amount of time devoted to the subject by the students of those regular courses which do not involve a knowledge of Chemistry as a prime necessity has been somewhat decreased, and the allotted time so distributed that now the entire course

in Elementary Chemistry is completed during the First Year, instead of extending over two years as formerly. This change was made with the present Second Year's Class during their First Year, and they in consequence suffered from the change, but that the effect of this concentration of work will be felt to be beneficial in the case of the present First Year's Class, I have not the slightest doubt.

Methods of Instruction. — A regular student of the First Year's Class now attends each week two exercises in the Laboratory (of two hours each), one recitation, and one lecture. Frequent *written recitations* and regular monthly *written examinations* serve to inform the student of progress made and to give warning if necessary. During the first term the laboratory exercises are devoted to chemical manipulation: each student performs, under the supervision of the Professor and of his assistants, a large number of experiments intended to illustrate the laws of chemical action, and the properties of all the more important chemical elements and their principal compounds. During the second term the laboratory exercises are devoted to the practical study of Qualitative Analysis.

The text-books used both in General Chemistry and in Qualitative Analysis, were prepared expressly to meet our own wants, and for use in our own laboratory.

Lectures. — The lectures, if indeed they can be designated by this term, are familiar expositions and are intended simply to aid the student by calling attention to the more essential points of the subject under discussion, and to allow the performing of a few important experiments which are either too complicated or too dangerous to be undertaken by beginners. At present the students are almost all entirely new to the subject, and, indeed, to any subject of like character, so that the multiplication of experiments beyond those described in the text-book used tends to confusion, and the performing of striking experiments involving complicated apparatus tends to distract the mind from the real point at issue. Hence the apparatus em-

ployed is of the simplest kind, and the lack of *lecture-apparatus* is not under the circumstances felt as a misfortune.

Instruction during the Second Year.—The students who pursue such courses as involve the subsequent study of Quantitative Analysis continue, during the first term of the Second Year, their laboratory work in Qualitative Analysis, and the students in the courses of Chemistry, Metallurgy, Natural History, Physics, Science and Literature, and Philosophy study the principles of Chemical Philosophy.

Assistants. — Except during the very early years of the School's history, the assistants have always been persons who have acquired their knowledge of chemistry in our own School and are, consequently, familiar with the usages and traditions of the laboratory. At present, two assistants during the first term, and one during the second term are assigned to aid in the instruction, but all the class work, — recitations and lectures, and the inspection and correction of the examination papers is entirely performed by the Professor himself.

Appliances.—It is perhaps not necessary to allude to the disadvantages under which the department of Elementary Chemistry labors in having only one Laboratory, and that none too spacious, in which must be given the instruction, both in chemical manipulation and in Qualitative Analysis, — a matter of less discomfort, to be sure, this year than last, when the laboratory was taxed to its utmost capacity. In addition to the regular classes the laboratory has also to accommodate a "Lowell" Class, and this year we have been obliged to encroach upon the little space remaining in the lower entry by the erection of temporary cases for the storage of apparatus.

Laboratory of Research. — Another need of this department of the Institute is a laboratory for the private work of the Professor. At present our only accommodation is a small room 25 by 23 feet, one portion of which is partitioned off for a weighing-room, and another portion for a hood. This room, which is also badly ventilated, is the only place afforded for analytical and other laboratory work to the Professor of Industrial Chem-

istry and his assistant, the Professor of Mining and his assistant and the Professor of General Chemistry and his assistant.* It seems appropriate that the Chemical Laboratory of the Institute of Technology should be a place to which chemical questions arising in the various departments of the State and also in the case of private individuals should be brought for solution. In spite of our limited accommodations which prevent us from making efforts for this kind of work, except during the summer vacation, considerable of such work has been done. The receipts, which are divided between the persons doing the work, and the "library-fund" of the chemical department, have enabled us to acquire some of the more important works of reference, — a nucleus of what we hope may some time grow into a sufficiently complete *working-library*. At present we have no proper place for its reception, as its separation from the acid fumes of the laboratory is impracticable owing to lack of space.

Although this is not strictly connected with the instruction in General Chemistry, I may in this connection allude to the investigation of certain scientific and practical questions undertaken at the request of the State Board of Health. These investigations have been as follows: —

1870. In the Second Annual Report of the Board of Health appears a report by W. R. Nichols, "On the action of Cochituate water on lead pipes," (recording the results of 10 determinations); also, a report by W. R. Nichols, "On the condition of Mystic Pond and its Sources of Supply," (involving some 100 separate determinations); also a report by A. H. Pearson of the results of more than 75 determinations of "The amount of carbonic acid in the air of various schoolhouses in Boston and in the outer air in different localities, and under different circumstances." These experiments were made under the direction of Professor Storer.

* The Professor of Analytical Chemistry occupies a corner of the chemical storeroom.

1871. The Third Annual Report of the State Board of Health contains a paper by Dr. F. W. Draper of Boston, "On the evil effects of the use of arsenic in certain green colors." Several analytical determinations made by Mr. A. H. Pearson in our laboratory are there recorded.

1872. The Fourth Annual Report contains a paper on "Sewage, Sewerage, etc., prepared by Dr. George Derby and Professor Nichols. The analytical work, involving some 1100 single determinations, was performed mainly by Miss E. H. Swallow in our laboratory. Investigation was also made into the character of certain slaughter house products.

1873. The Fifth Annual report contains a paper by Professor Nichols, "On the present condition of certain rivers of Massachusetts, etc." The analytical work involved more than 1300 single determinations, nearly all made by Miss E. H. Swallow, one of our graduates.

1874. The present year, for sufficient reasons, not very much has been done; still it is hoped that an investigation now in progress, the results of which will appear in the Sixth Annual Report of the State Board of Health, may not be without interest and value, and another research more important in its practical bearings is a portion of the work laid out for next year.

The advantages to the Institute in thus being recognized in the service of the State seems to me not unimportant, and the pecuniary return more than covers all expenditure for gas, water and chemicals, so that the Institute incurs no expense directly or indirectly, in the matter.

All of which is respectfully submitted.

WM. RIPLEY NICHOLS,

Professor of General Chemistry.

REPORT OF WORK IN THE DEPARTMENT OF PHILOSOPHY.

To the President: —

By the changes consequent upon the new Course of Study, adopted last January, the work devolving upon my chair is now divided into two distinct parts: (1) that required of all regular students, as a condition of a degree in any department; and (2) that required, in addition, of regular students in the department of Philosophy,— a department created at the time of adopting the new course. The report of what I have done the present year, may conveniently treat of these two parts separately.

I. THE WORK DONE WITH ALL REGULAR STUDENTS.

This, during the first half year, before the new course went into operation, comprised (1) two lectures a week, on the Syllogism, and on the Rudiments of Inductive Logic, with the Fourth Year's Class; (2) two lectures a week, on the Doctrine of Terms and Propositions, with the Third Year's Class; and (3) one lecture a week, on the Structure and Analysis of Terms and Sentences, with the First Year's Class. For this last, the class was divided into two sections.

The work, on the part of the Fourth and First Year's Classes, was of a high order; both passed a very thorough

examination at the Semi-annual in January. I was able to use far more complete and difficult papers than those of the preceding year, and yet the results were quite as good. This examination brought my connection with the Fourth Year's Class to a close; and their performance of duty, throughout my acquaintance with them, has seemed to me so unusually commendable, that I cannot dismiss them from this report without a special acknowledgment of the industry, sympathy, intelligence, and success which have constantly marked them while under my instruction.

The work with the Third Year's Class was broken short in the midst, by the operation of the new courses. This interruption of plans laid out and worked upon before any definite knowledge of the proposed changes was in my possession, of course made the subject appear to the class in a very incomplete and unsatisfactory light, and caused the semi-annual examination in it to seem unreasonable. Nevertheless, they succeeded in passing a paper of unusual difficulty with decided credit, only three out of the forty-seven members of the class having been subjected to conditions.

With the opening of the second half year, in February, the new course went into operation. It was, however, decided to let my plans for the First Year's Class go on as laid out at the beginning of the year. I therefore continued to lecture to them once a week till the year closed.

My regular work with the Second Year's Class now commenced, and occupied three lectures a week for the remainder of the year, covering in outline the whole subject of Formal Logic, exclusive of Fallacies. The result with this class seems to indicate that the place and time allotted in the new course of study to the subject of Logic (the second half of the Second Year), can be made to answer a more useful purpose than I had thought they could. Although the *amount* of ground covered has been less than I should like to see, as the limit to be reached in that study in the Institute, the quality of the work has been good. In future, too, I believe we shall be

able to include in our work not only the positive theory of the Syllogism, but the doctrine of Fallacies as well. I hope to accomplish this by finishing so much of the theory of Propositions in the First Year's work, as will enable us to commence the instruction of the Second with the doctrine of Inferences. To make sure of this, however, I recommend that the Institute shall in future require, as a condition for entering the First Year, a thorough acquaintance with the classification and analysis of terms, and with the parts of a proposition, and a respectable skill in analyzing sentences, both simple and complex.

As to methods of instruction, I may refer to my report of last year. The only change has been, to increase somewhat the number of preliminary written examinations, held at intervals during the progress of the lectures. These have averaged, for each class, about one in three weeks throughout the present year.

II. THE WORK IN THE DEPARTMENT OF PHILOSOPHY PROPER.

In this new department, placed under my charge, there have been enrolled, the last half-year, five students: three regulars — one of the Second Year and two of the Third — and two specials. The latter took the introductory course in Psychology prescribed for the Third Year, and the course in Ethics prescribed for the Fourth Year.

The programme of work, as shown in the course of study printed in the last annual catalogue, has been quite completely carried out. The five students, without exception, have passed successful examinations, — a fact the less remarkable, when it is recollected that they are all students from preference, having chosen the department from a conviction of its adaption to their wants, and from a sincere interest in its leading subject.

The instruction has been given directly by lectures, three a week on a general introduction to Philosophy, and on Psychology, and three a week on Ethics. Much reference of the students to standard texts as companions to these lectures, has

however, been employed. For this purpose, I have used, with the Third Year men, Bowen's edition of Sir W. Hamilton's *Metaphysics*, portions of Stirling's translation of Schwegler's *History of Philosophy*, portions of Mill's *Logic* and of his *Examination of Hamilton*, parts of Ueberweg's *History of Philosophy*, and of the *Prolegomena* to Krauth's edition of Berkeley's *Principles of Human Knowledge*, and Masson's *Recent British Philosophy*. The Fourth Year Specials have read and discussed the most important parts of Calderwood's *Handbook of Moral Philosophy*, together with an outline of Kant's theories in the field of Ethics. Both classes have done a considerable amount of parallel reading on their own account.

The range and character of the work done will be clearly seen in the subjoined papers, used at the annual examination in May: —

DEPARTMENT OF PHILOSOPHY.

PSYCHOLOGY — THIRD YEAR.

May 22, 1874.

1. If we regard the subject merely from beforehand, what may we lay down as a provisional definition (or description) of Philosophy? Can you see any reason in this, why Plato should have called it a "meditation of death"?

2. If we attempt a scientific definition of it, after effectual acquaintance with its procedure and its results, what threefold distinction in regard to it must we make in order to avoid confusion, and to prevent us from supposing definitions to conflict, which are in reality quite harmonious?

3. Keeping this distinction in mind, endeavor now to define Philosophy from each of the three points of view.

4. In the light of what precedes, what would you say of Hamilton's statement that Aristotle, in calling Philosophy "the art of arts, and the science of sciences," merely intended to describe its supreme eminence? What, probably, *did* Aristotle mean?

5. In general, what two great fields does Philosophy include? Distinguish between them as accurately as possible.

6. Tabulate the schools of Philosophy, as they have thus far appeared in history, arranged upon the principle of their *Theory of Knowing.*

7. Do the same, upon the principle of their *Doctrine of Being.*

8. Endeavor to make out a division of them according to their *Method of Research.*

9. State the doctrine of the Relativity of Knowledge in its most general, least determinate form, i. e., as held in common by *all* Relativists.

And the form it assumes in the hands of Transcendentalists.

And the intense form of it peculiar to Empiricists.

Are these two schools necessarily Relativist?

10. Why may Kant's "Critical" philosophy justly be termed Transcendental Skepticism? Why is Hume's called Empirical Skepticism? Is there any essential difference in their theoretical results? In their practical?

11. How does Hume's Skepticism differ from Nihilism? How can you account for its being so repeatedly charged by able men with being essentially the same doctrine?

12. How would you distinguish a *Person* from an *Individual*; or, more exactly, *personality* from *individuality*?

13. State the doctrine of the Trinity, as involved in Pure Consciousness — i. e., in the *Idea of Personality.*

14. In what sense does this Trinity "appear" in Consciousness the Sensation, and in what sense not?

15. Where do the English, the Scottish, and the Positivist schools of Philosophy all essentially agree in placing the "Beginning" of science? Why must this render it certain beforehand that they can never establish Substantive Being? What does this show in general, in regard to the effect upon Philosophy of the Psychologic starting-point?

16. In what peculiar manner does Hamilton regard the term *Psychology*? In what way does he then divide the field which he thus denotes? In doing this, what further departure does he make from the general usage of philosophers? Is the *distinction itself* which he makes here valid? Give your reasons.

17. When Calderwood says that the Ego is given *immediately* in consciousness, what does he mean, and what criticism may be made upon his view?

18. Distinguish between "consciousness" and "self-consciousness." State Hamilton's peculiar views in this connection, and criticise them, both from his own contradictions and from the facts.

19. Why is Hamilton's philosophy of Perception called *Natural* Realism? Why *Dualistic* Realism? Where does he find the theoretic warrant for his two Substances?

20. Give Hamilton's classification and nomenclature of the "Faculties" — and the common names along with his technical ones. What *is* a "faculty"?

DEPARTMENT OF PHILOSOPHY — YEARS III, IV.

EXAMINATION IN ETHICS.

May 25, 1874.

I.

Write as complete and as accurate an account as you can, of the so-called *Intuitional Theory of Morals.*

Show what it is intended as a theory to account for; making all the necessary distinctions between processes of knowing, of feeling, and of acting.

Show how it finds the warrant for obligation, having defined Obligation.

Show, also, how it states the universal *Law of Virtue*, i. e., in what it makes Virtue essentially to consist, irrespective of the particular form.

Show the peculiar difficulties to which the theory is liable, and how its advocates attempt to overcome them.

Show the distinction between Judgments of Right and Judgments of Duty. Decide whether Calderwood, under this distinction, really includes all the vital facts of moral consciousness. If you think he omits any, show what, and why you think so.

Discuss Conscience. Point out the distinction between Rights and Right.

Make as good a list as you can of what Intuitionalists generally consider the *à priori* First Principles of Right.

II.

Present a similar treatment of the so-called *Development Theory of Morals*, going into details as far as you have time. Take especial

notice of its doctrine concerning the origin of knowledge in general, the origin of conscience in particular, and of its most general Principle of Rectitude.

III.

Make a list of the leading philosophers who have advocated either view.

It deserves mention, that, although answers to but half of the foregoing questions were *required* of the students, and the students were allowed to select this portion for themselves, they voluntarily offered answers to all, and that a great majority of these answers were satisfactory.

I think these results entirely justify the course of the Government in creating this new department. To ensure its complete success, I believe it will only be necessary to carry out, as far as possible, with respect to it, the principle of equipment with the requisite implements and laboratories (if I may be allowed the expression), which characterizes the administration of instruction in the other departments of the Institute. The proper "laboratory" of a department of Philosophy, is, of course, a sufficient collection of the works of those thinkers who have really contributed to the historical development of Philosophy, together with such illustrative commentaries and charts presenting systematic views as wholes, as will serve at once to instruct the student and to stimulate him to independent investigation. In short, the need is a good special *library*, properly arranged for rapid consultation, and yet in some place suited also for the most patient study, with appliances enabling the student to make his own abstracts and charts of systems, where such are needed.

The beginning of such a library has been put in our possession. The department has now a room sufficient for its immediate wants, and the nucleus of a special collection in philosophy, from a small appropriation assigned us during the year, is already obtained. This, together with the works in my own collection, will answer all purposes, provided it can gradually

be increased as the department goes on. A very small annual appropriation for this object — so little, even, as fifty dollars a year — will serve to meet the probable wants of the department as it develops, and, in the course of time, to secure a positively *complete* collection of such works as are of any real significance in this field of knowledge.

The progress of my instruction in this department has already convinced me that important alterations must be made in its course of study as printed in the last catalogue. More time must be assigned to its special subjects in the Third and Fourth Years, and those subjects must be brought in a prominent and special form into the Second Year. To make room for these changes, certain of the miscellaneous studies, now pursued by students of this department in common with those of other departments, must be dropped. The details of these alterations will be presented to the consideration of the Faculty at an early day in the ensuing year.

Respectfully submitted,

GEO. H. HOWISON.

Boston, June, 1874.

REPORT UPON THE LOWELL SCHOOL OF PRACTICAL DESIGN.

Mr. President: —

At the close of the second year I have the honor to submit the following Report of the progress attained in this Department: —

The second annual session of this school commenced with twenty-six pupils, — fifteen old and eleven new ones. The old pupils started at the beginning of the year, upon original compositions; and gradually so improved, that the results proved highly satisfactory to me, and commendable to themselves.

The new pupils after working from copies until January, and having gained skill in execution, were put upon such variations of work as naturally lead them to produce original compositions. This change proved also, in the highest degree, beneficial, and all of them exhibited great originality in their subsequent efforts at composing.

During the month of May last, I sent from time to time all the original designs, from both classes, to different manufacturers, for inspection; and every manufacturer who saw our samples, purchased some of them. Thus 23 patterns were disposed of to the amount of $200 — each pupil receiving the money for his or her specimens.

Two young designers have been furnished, from the advanced class, to the Pacific Mills, where they are now perma-

nently engaged, giving great satisfaction. We have had two public Exhibitions, one at Horticultural Hall, Boston, and one at Huntington Hall, Lowell — which have proved highly attractive and interesting to the public.

The school also contributed to the art department at the late exhibition of the Mechanics Charitable Association, held in Boston, and was awarded a prize of a gold medal.

I am happy to add that the pupils in this school evince great application and perseverance in their studies, as well as good will; and I can very confidently affirm that their patterns exhibit generally a goodly share of taste and originality in design.

It is with great pleasure that I am able now to state that, in my judgment, we shall be able hereafter to furnish from this school well qualified American designers, in all branches of this important art.

The generous contribution made last year by Mr. James L. Little, has not yet been exhausted. The "Claude Fréres patterns," furnished to the School, by Mr. Lowell, have proved an invaluable aid in the work of the past year.

I am, very respectfully,

Your Ob't Serv't.

CHA'S. KASTNER.

THE DEPARTMENT OF ARCHITECTURE.

President Runkle:—

DEAR SIR: — The instruction given during the last year in the Department of Architecture did not materially differ in character from that of the previous year. Three regular students and about twenty special students have been in attendance, about the same number as in previous years. But the quality of the classes visibly improves from year to year, partly because it has been found that young men without either character or intelligence are no better suited for these studies than for others, so that we are no longer troubled by their presence, partly because the department has come to be favorably known in the more distant parts of the country, and, other things being equal, students who come a long distance are in general the best workers. It has accordingly happened that the results of the year's work have been more satisfactory than in any previous year, as good work has been done and more of the work has been good.

At the beginning of the year one of the two students who passed the final examinations the previous year presented his thesis and received his degree. The subject chosen was a building for water-works in a public park. The drawings showed the arrangement and aspect of the building itself, with the machinery for pumping and controlling the water. The text accompanying them contained calculations of the dimen-

sions of the principal parts of the structure and of the flow and supply of the water.

During the year the rule was adopted that the graduating thesis should be presented before the close of the school year. A second thesis and the accompanying drawings was accordingly presented in May, by the student who passed his final examinations at that time. The subject chosen was a Railway Station, situated on a bridge over the track. The drawings showed the structure in plan, elevation and section, with details of the wood, iron and stone work. The thesis itself discussed the thrust and equilibrium of the arches, the strength of the retaining walls, the resistance of the tower to wind, etc., etc.

The Third Year's class, to which most of the special students were attached, were occupied during the year with the following problems: — 1, an arch; 2, a *Porte-cochère*; 3, a Portico; 4, a Peristyle; 5, a Staircase; 6, a Billiard Room; 7, a Pompeian House; 8, the use of Four columns; 9, a Monumental Bridge; 10, a School of Architecture; 11, a Dwelling House. At the same time the Fourth Year's class made designs for 1, a Temple Tomb; 2, an Iron Pavilion; 3, a *Café Chantant*; 4, a School House; 5, a Railway Station. This class also made sketches of most of the problems given out to the other class. They also made careful drawings of King's Chapel, to which the Wardens kindly allowed them access at convenient hours. Two of the designs for the Railway Station were given in the September number of the Architectural Sketch Book, a professional journal published by Messrs. Osgood & Co.

The course of History this year covered the Greek and Roman Period, as usual, in the first half of the year, and in the last half the period of the Renaissance. The usual lectures in construction were continued through the year. The collections have not been materially increased.

I am, very truly,

Your Ob't Serv't,

WILLIAM R. WARE.

REPORT OF THE DEPARTMENT OF MILITARY INSTRUCTION.

President J. D. Runkle: —

SIR: — Since rendering my last report, the discipline and efficiency of the corps of students receiving military instruction has been much improved, and comparatively little discontent is now apparent. I have endeavored to make the instruction as little burdensome as was consistent with making it efficient. The instruction was given under many disadvantages, not the least of which was the want of a proper drill-room. Whilst the disciplinary rules which were adopted were neither harsh nor severe in themselves, they were felt as irksome by some of the students who had been accustomed to the comparatively loose discipline, or rather, absence of discipline, which prevailed previous to my reporting for duty. I have observed that the few cases which were at all troublesome were invariably those of students who were troublesome in other departments of the Institute. The inference then is fair, that the difficulties of making the military instruction at the Institute both respectable and efficient, are not inherent in its incompatibility with the strictly civil character and proper work of the school, but rest more particularly with the individual character of its students. In order to make military instruction effective, military discipline must be enforced during the hours assigned for that purpose. This discipline is necessarily more minute and less yield-

ing than the ordinary discipline of a civil school, such as the Institute of Technology. But the inflexible exercise of it, at stated times, must have a tendency to make the students more amenable to the general discipline of the school, and of rendering impossible the stay of those unruly characters whose presence is injurious than otherwise.

In addition to the instruction in infantry drill, some instruction was given in artillery drill and signalling. Voluntary practice in day and night signalling was given at distances between stations ranging from one to six miles, and many of the students became skillful therein. The success of this instruction is due chiefly to the able efforts of Mr. Henry N. Mudge, who was Signal and Ordnance Officer during the greater portion of the year. Aside from its utility as a military exercise, the instruction in signalling may be useful to the students whenever they may be called upon to perform surveying, or other similar out-of-door work. It enables them to communicate at distances far beyond the reach of the human voice, but within the range of vision. It requires no special apparatus or preparation for either day or night communication.

Lectures were given on the following subjects, viz:

1st. "Discipline"—manner of establishing and enforcing it.

2d. "Feeding troops"—ingredients, proportions and manner of preparing food in camp and on the march.

3d. "Military Hygiene"—sanitary measures necessary in camp and on the march.

4th. "Military Courts"—composition of, principles governing their actions, and the forms of procedure.

It is my intention to continue with the second year class, during the school year of 1874–75, the lectures upon the 3d of the above mentioned subjects. My aim in giving these lectures is to give the instruction which is essential to the proper care and preservation of the health and efficiency of troops when exposed to the abnormal conditions of the camp and the march. This instruction may be useful to the students when, as engineers, they are called upon to assume charge of large bodies

of workmen in the construction of railroads, or other similar work. A knowledge of the proper manner of feeding and taking care of these laborers can not but increase the efficiency of their services, and the amount of work accomplished in a given time.

The lectures upon Military Courts were given with a view of enabling the students to enforce their own discipline by courts composed of the officers of the corps.

The officers of the corps labored under great disadvantages in the instruction of their respective commands. There was such an absolute certainty of a change in the then existing system of tactics, that they felt and received but little encouragement in studying up the details which are so essential in acquiring proficiency of drill. They are deserving of much credit for the thoroughness with which they performed all duties assigned them. I beg leave to mention their names in this report, viz.:

STAFF OFFICERS RANKING AS FIRST LIEUTENANTS.

Adjutant,	B. Leighton Beal.
Quartermaster,	F. M. Learned.
Signal and Ordnance Officer,	H. N. Mudge, resigned, succeeded by C. H. Goodrich.

	Captains.	*1st Lieuts.*	*2d Lieuts.*
Co. A.	T. Aspinwall, Jr.	G. C. Avery.	C. L. Dennett.
Co. B.	T. E. Schwarz.	W. D. Townsend.	J. B. Henck, Jr.
Co. C.	W. R. Munroe.	W. R. Cabot.	J. M. Wilson.
Co. D.	C. F. Main.	E. L. Caldwell.	S. W. Holman.

At the close of the school year, about fifty students desired to go into a voluntary encampment for a week. It was not at that time considered expedient to permit them to do so. Such encampment coming immediately after the severe tasks imposed by the annual examinations would serve as a most healthful relaxation, enabling me, at the same time, to impart some useful instruction. The experience would be such as to be useful to them as engineers, when required by their work to live in tents. Opportunities would be afforded for base ball, foot ball,

and other healthful out-of-door sports. Whilst such an encampment would serve as a recreation to the students, I feel confident that it will go far, from the pleasant associations which it will undoubtedly engender, in making more acceptable the military instruction, absolutely required as it is. I trust therefore that permission will be granted for this purpose.

So much of the school year of 1874–75 has elapsed at the time of writing this report, that I take the opportunity to briefly mention some of the changes which have been made during that time.

As a mistaken impression regarding the relative status of the military element seemed to have been gaining ground in the minds of some of the friends of the Institute, every effort, consistent with its efficiency, has been made to render it as little conspicuous in appearance as it is in fact. With this in view, black gutta-percha buttons have been substituted for the bright metallic buttons heretofore worn. The uniform, thus changed, is inconspicuous.

In compliance with the recommendation embodied in the report of the Committee of the Corporation "On the Military Instruction given at the Institute of Technology," the amount of writing necessary in the transaction of official business has been reduced as far as practicable. The amount of "red-tape," so called, which was demanded of the majority of students, has been much exaggerated. It was, in fact, a demand of less than *five* minutes labor in writing explanation for one or more absences from *required* exercises, and but little more than *one* minute's labor in writing an explanation of tardiness.

The manner of appointing the officers is somewhat different than that of last year. Only *acting* appointments have been made, subject to approval and confirmation by the Faculty. The *full* appointments will be made after the semi-annual examination, at which time they will doubtless have shown their degree of fitness for different offices. The details of instruction and discipline have been left, in a greater measure than last year, in the hands and control of the officers. They have

performed their duties with a sound judgment and discretion. The burden of the responsibility in disciplining and instructing the corps has rested upon the acting Captains commanding companies. I would ask no better fortune, should I be called upon to organize a regiment for actual service, than to have these young gentlemen as my assistants. The acting Adjutant, Quartermaster and Signal and Ordnance Officer have efficiently performed essentially the same duties which they would be called upon to perform in actual service. The roster of acting commissioned officers is as follows, viz.:

STAFF OFFICERS RANKING AS FIRST LIEUTENANTS.

Adjutant,	J. F. Swain.
Quartermaster,	E. H. Gowing.
Signal and Ordnance Officer,	C. Cushing, Jr.

	Captains.	*1st Lieuts.*	*2d Lieuts.*
Co. A.	A. K. Plimpton.	W. E. Chamberlin.	W. B. Bradford.
Co. B.	C. H. Norton.	C. H. Fisher.	W. S. Frost.
Co. C.	F. E. Peabody.	H. E. Monroe.	W. M. Peters.
Co. D.	W. Jenney.	I. M. Story.	F. P. Spalding.

The report of the Committee (previously mentioned) leaves nothing for me to say regarding the beneficial effects of military instruction, from physical and mental points of view, nor of its necessity from patriotic motives and an honest intention to comply with the spirit, as well as the letter, of the terms of an obligation assumed. I feel confident that the graduates of the Institute will serve with credit in the ranks of the citizen soldiery, should they be called upon to defend their homes and liberties.

Respectfully submitted,

E. L. ZALINSKI,

1st Lieut. 5th U. S. Art'y.

REPORT ON MILITARY INSTRUCTION.

The Committee appointed by the Corporation of the Institute "to take into consideration the whole subject of the military instruction to be given in the Institute," beg leave to present the following

REPORT.

Chapter 186 of the Acts and Resolves of the Legislature of Massachusetts for 1863, contains the following provision, namely: "Said Institute of Technology, in addition to the objects set forth in its Act of Incorporation, shall provide for instruction in military tactics." This condition forms part of the Act which appropriates to the Institute one-third part of the annual interest or income received from the fund created by Act of Congress approved July 2d, 1862, granting public lands of the United States for certain purposes of education.

So long, therefore, as the Institute shall continue to receive this endowment, "instruction in military tactics" seems to form a necessary part of its curriculum.

Accepting this condition as imperative, the only questions open for consideration respecting military instruction must relate to the amount, the kind, and the modes of imparting it. It is hardly possible in a report of this kind to discuss fully the value, either absolute or relative, of instruction in military tactics; a few considerations may be presented. And first of all, it is well to remember that at the time when the Legislature

selected the Institute of Technology as one of the institutions which might receive the national bounty for educational purposes, the country had but recently entered upon the great civil war, when its untrained army, composed largely of volunteers, almost wholly destitute of military knowledge and practice, were encountering the fatigues of the march and the camp, and the perils of the battle-field. Surely any provision which is the offspring of such a crisis as liberty or slavery, of life or death, must be regarded with the deepest interest. In any country, however peaceful, yet subject to the exigencies of war, and relying less upon the strength of a standing army than upon the patriotic response of its citizens to any necessary call to arms, the value of some practical knowledge of military tactics by its people, and especially by its educated classes, is too obvious to need argument. A striking illustration is given in a communication written at the time of which we are speaking, concerning the students at the United States Naval Academy, at Annapolis.

"When Washington was defenceless, Baltimore in riot, and all Maryland in a state of revolt, communication being cut off at Annapolis, there was great fear of an attack upon that important strategic point. The pupils were prepared for any exigency, and slept with their loaded rifles over their cots. At an alarm of a night attack, there was no hesitation among those gallant little fellows. They were up directly; fell in their ranks and off at *double quick* for the point of danger in an almost incredible short space of time. The elder boys dragged their howitzer with them. Had an attack taken place, those pupils would have given a good account of themselves, and have stood their ground with courage and steadiness. The secret of this is *discipline*, for which they are indebted to the assiduity of their brave and experienced Superintendent, Captain Blake, of the Navy."

Had even a tithe of this military discipline been received by the men who composed the loyal army at the beginning of the war, how vast might have been the saving of life, of suffering and of property! It was doubtless the inevitable recognition

of this fact which induced the Legislature to impose the condition, that those who participated in the benefits of the national bounty for educational purposes in this Institute, should become qualified to return a special service in the field, should such be required for the national honor and welfare. The national academies of military and naval science and practice will continue to afford the means of educating a limited number of officers for the regular Army and Navy on a peace basis; but it is neither practicable nor desirable so to enlarge these institutions as to embrace corps of students sufficient in number to lead the volunteer forces in case of war. It is not desirable to cultivate a warlike spirit among our people, nor to withdraw from civil pursuits, to be maintained at the public cost, a needless force of military men. The safest and most feasible alternative seems to be found in making instruction in military tactics a part of the curriculum of our higher schools. As the country shall increase in extent and population, and these institutions in wealth and diversity, it may be useful and desirable, should the domestic and foreign relations of the country require an increase of military men of high culture, to establish in some of them departments of military science as parts of a university system. No such department has been established in the Institute of Technology, and none is now recommended. Since, however, instruction in military tactics is promised by accepting the legislative bounty, it is doubtless the purpose of the Corporation that this obligation shall be fulfilled in the true spirit and intent of the statute, and in such manner and with such results as shall correspond with the general vigor and thoroughness of study and discipline in all other departments of the Institution. In the opinion of your committee, the value of military instruction and discipline is by no means to be estimated alone by their possible relations to a state of war, when the citizen is transformed into the soldier. Such instruction has great and peculiar value as an educational and disciplinary agency, and as a sanitary exercise of the highest type. It cultivates habits of neatness, order, precision, quickness of

thought and action, and that absolute obedience which those must first learn who are afterwards fit to command. It inspires a manly and chivalric spirit, gives ease of carriage and movement, develops muscular energy and endurance, and stimulates the intellectual powers by kindling all the vital forces into healthy activity. If, therefore, education be interpreted as a process of developing the intellectual faculties, as well as a mode of receiving and classifying knowledge, it is believed that military tactics compare most favorably as a branch of study, with certain branches of mathematics, and with many other studies which especially engender habits of concentration and persistent application. Military practice is certainly superior to either in the particular that it blends recreation with acquisition. If we mistake not, the courses of study in the National Military Academies are as difficult of accomplishment as are those in the average of American colleges; and yet they are completed in as many months as the college courses, notwithstanding students in the former are subjected to frequent and protracted military exercises daily. And testimony is abundant to prove that the time employed in the military drill is more than accounted for in the increased mental activity and energy which it produces. In a letter to the chairman of this committee, Rear Admiral Worden, Superintendent of the United States Naval Academy, says:

"The average time assigned to the drill of each student during the academic year (eight months) is seven hours per week. This includes the time occupied by all seamanship, Great Guns, Field Artillery, Boat Howitzers, Infantry, Fencing and Boxing Exercises and Dress Parades. Besides these exercises, those members of the Fourth Class who enter in June, are practised in gymnastics during the summer months, three hours every week, and in swimming every morning. The Third Class has instruction in gymnastics about three hours per month; and all the classes are invited and encouraged to use the Gymnasium for exercise during recreation hours. The average time assigned to drill in Infantry tactics does not exceed two hours per week throughout the academic year. . . . . As to the

amount of drill which can be profitably employed in such a school as the Massachusetts Institute of Technology, for purposes of exercise, discipline, etc., I am of opinion that one hour per day could be so appropriated with great advantage to the physical culture and mental development of the students. . . . . I have always been strongly impressed with the necessity of bodily culture as the true complement of mental development; and I know of no readier and more congenial method of obtaining a good result than the practice of military exercises in the full meaning of that term. For in that sense what is called military training — a kind of training which is but a small part of a military education, and which ought to be *common* and not peculiar to soldiers and sailors — is to be valued not only in a muscular point of view, but as generating habits of just subordination, of manly self-control and of neatness and good order in person and personal property."

Admiral Worden also refers in his valuable letter to an elaborate article on "Physical and Military Exercise in Public Schools — a National necessity," contributed by General Edward L. Molineux, of New York, to Barnard's "Military Systems of Education," first published in 1862, and revised in 1872. In this article we find the following suggestions:

"The influence of health upon the faculties of the mind is acknowledged by all, and yet how few in this country devote attention to those important exercises which are necessary to the preservation of health, and without which intellectual power cannot be applied to its highest use. The talents, the experience of our best educators of youth are taxed to devise exercises to develop the *mental* faculties, forgetting that too close application to study is detrimental to the growth of the body. . . . . What then is the most simple, feasible and useful plan to adopt for physical exercise in our colleges, normal and public schools? We unhesitatingly reply that the only successful, orderly and systematic method is to engraft them upon the course of studies during school hours, and to carry it out under strict military discipline; the exercises being such as are best suited to the ages, strength and capabilities of the pupils, namely: calisthenics and walking for the girls and younger children, and military exercises for the elder boys."

fully asserted and admitted, as are those of any other department.

"Instruction in military tactics" should not be regarded as an excrescent and superfluous innovation, but as an established and important element in the course of study and discipline; fulfilling thus the reasonable expectation created by the list of "Officers of Instruction," presented in our Catalogue, where there is embraced a "Professor of Military Science and Tactics." Any attempt to unduly compromise it, or subordinate it, would be to paralyze its usefulness and success, and bring it into disrepute with the students and the public. There should be no attempt to hide it from view, nor to apologize for its existence. It is due to the public and to the Commonwealth, that it shall be widely known and fully understood that instruction in military tactics forms part of the curriculum of the Institute; and that compliance with regulations concerning it, and proficiency attained in it, will be required and accounted in the meritorious standing of students in those classes in whose course of study it is found. If, then, there be students who do not wish to receive this instruction to the extent now established in the Institute, they will not be deceived by coming where by law and good judgment it is required; and no prejudicial errors will vex the public mind in consequence of any doubtful or hesitating policy upon a subject which is held in favor by many of the best educators in the world, and which seems to be gaining strength by every day's experience.

Complaints will doubtless be made by the indolent and unaspiring against all strict and positive discipline, without which excellence is seldom attained. And if the standard be lowered to meet the demand of those who would perhaps be most injured by concession, there will still be a class below who will renew the complaint; while the ambitious and hopeful student will delight in the discipline which imparts health to his body and vigor to his mind, at the same time that it measurably prepares him to discharge the highest obligations of patriotism in the hour of his country's peril. The last fear that need be

entertained is that the Institute shall excel in this attractive and important branch of instruction to a degree commensurate with its success in all other branches embraced in its Catalogue.

The committee do not recommend any other kind of military instruction than the Infantry drill already established, and what is necessarily connected with it. The Artillery and Cavalry practice, however desirable in an institution thoroughly military, and necessary to the professional soldier, are not compatible with the appointments of this Institution, nor consistent with its purposes and objects. Even within the course of instruction and practice in the Infantry drill, as now conducted, it is quite possible that the requirements in respect to certain clerical details, such as daily reports, orders, requisitions, etc., may be needlessly onerous, and that they consume time which might be more profitably employed by the officers to whom such duties are assigned. The committee recommend such modification in this particular as shall remove all ground of reasonable objection. We are of opinion that such modification may be profitable.

Two collateral topics have engaged our attention, namely: a uniform for the students and a hall for drill, which may also serve the purpose of a Gymnasium. A uniform of some kind appeared to have been agreed upon before the committee was appointed; and thus the necessity, or at least its expediency, was conceded. A sample coat of gray cloth with elaborate trimming of black braid and gilt buttons was exhibited as a style of uniform which could be obtained at moderate and satisfactory cost. This seemed to the committee too conspicuous for the purpose, and not in good taste otherwise. After some investigation and inquiry, a uniform was designed of plain blue cloth, of the Middlesex Mills, with very little trimming, and of so simple decoration generally as to be distinctive without being offensively conspicuous. It consists of a frock coat, vest and pantaloons and cap, all of the same color and material. The buttons are the badge of the Institute, provided by it, as is customary with other institutions. This uniform is furnished to

the students at very small advance upon its cost to the manufacturer, and at less price than the original sample here described; and it has been generally approved for its neatness and suitableness to its purpose. The matter of a drill hall is one of much greater importance and difficulty to decide. It is manifestly very desirable that all the studies and exercises of the students shall be conducted at the Institute; and especially is this necessary for this study, if by unanimous assent of the Corporation and Faculty two hours per week, the present allotment, be all that can be allowed, and yet the least that can be used to any profit for military instruction. Any abridgment of this time in travelling to and from some remote hall must be proportionably detrimental. Indeed the great want of a drill hall at the Institute is conceded; and the only, or the chief, obstacle to its erection is the lack of the necessary funds.

No better plan than that suggested by Prof. Zalinski, of a temporary building, has occurred to this committee, and while it is not what we desire, not what can be accepted as permanent and sufficient, yet the need of some place for the purposes mentioned is so urgent and immediate, that we recommend the adoption of this one as the best that is available, and the least likely to interfere with other interests and purposes for which funds must be immediately provided.

All of which is respectfully submitted,

ALEX. H. RICE,
JOHN CUMMINGS,
EDW. ATKINSON.

Boston, June 16th, 1874.

EXPEDITION OF MINING STUDENTS TO LAKE SUPERIOR.

The professional courses of the Institute of Technology, as a rule, give a student a fair insight into his profession without going far from the city of Boston.

For the mechanical engineers there are shops, works, and factories, in the vicinity of Boston, that can be visited to give life and reality to the instruction by the Professor. For the civil engineering course there are bridges, railroads, depots, and water works, etc. The architects have buildings always at hand. The analytical chemist can learn the use of his tools in the laboratory. There seems, however, a peculiar need that the mining engineers and metallurgists should make expeditions to a great distance from the school as there are no neighbouring mining regions; if there were, there would also be other dissimilar regions at a distance. The effort to make a mining engineer without showing him a mine would be as fruitless in its result as the effort to make a sailor without allowing him to go to sea.

For these reasons it is all important that visits should be made by the students of this course to the various mining regions of the country.

Although the ores of iron, copper, lead, and silver, and the seams of different kinds of coal are all of them mined by different methods, undergo a different subsequent treatment, and occur in dissimilar deposits, still a person while visiting one mining region gains much that will be [illegible] to him in studying

other districts. It would be impossible in the limited time that can be devoted to expeditions, to visit a great variety of regions. It is stated in the catalogue that each mining student shall have at least one opportunity to visit one mining district during his course at the school.

The following instruments have recently been added to the equipment of the mining department especially for use on these expeditions: — a light mining transit and the German markscheide instrument with its grad-bogen.

It is deemed advisable that the second, third and fourth year's classes shall all be liable to receive the invitation to go upon expeditions. The second year will start to be sure entirely ignorant of the subject, but the expedition will add reality and interest to the subject when studied in the following year. The third year will make the excursion almost contemporaneously with their course of lectures. The fourth year, although they make the expedition a year later, yet it serves to brush up the subject in a practical way, and gives them opportunity to look about for places. There can be no fixed rule as to which classes should go on the expedition in any given calendar year, as circumstances come in to modify the case in regard to expense, time taken, and the number wishing to go.

An expedition during the summer of 1874 was made to the mining regions of Lake Superior. The party numbered fifteen, and contained members of the three professional years besides the two Professors in charge of the party.

While passing over the New York Central Railroad the party spent a day in studying the very extensive and carefully systematized salt works of Syracuse. The courteous attention of Dr. Englehardt added much to the mental enjoyment of the day, as did the thoughtful provision of Mr. J. W. Barker and of Mr. M. D. Burnett, to the physical comfort of the party. A day of recreation was spent at Niagara. The party were very kindly received by Mr. Grout of the Lake Superior Copper Smelting Company's works at Detroit. After two and a half days of pleasant sailing upon the lakes the steamer came to its

destination at Houghton, a town situated in the heart of the copper region. While at Houghton visits were made to the Pewabic mill under the superintendence of Mr. Uren. The low pressure engine is run on the exhaust steam from the Ball stamp; the pressure used is but one pound per square inch, the atmosphere doing the work.

At the Lake Superior Copper Smelting Company's works the students were in clover. Mr. James R. Cooper spared no pains to make the morning pleasant and instructive. The works are an example of neatness and order. Not a pound of copper is allowed to go to loss without being challenged by the most available methods to prevent it. Mr. M. B. Patch (graduate of Mass. Inst. Tech.) added much to the profit of the visit by explaining matters.

At the Quincy mill the large battery of heavy cam shaft stamps was a great object of interest, as they are probably the heaviest stamps of this pattern in the country. It was to Mr. L. E. Emerson and to Captain John Cliff that the party owed a very pleasant morning within the Quincy mine. The party went down the man engine calling "change" at every step. The prospecting within this mine is far ahead of the stoping. The mine excellently illustrates the value of a cross cut from a barren part of the vein to prospect its adjacent productive spot.

The Atlantic mill was visited by a few of the party. It is a very complete mill; the ore worked in it is difficult of treatment. Mr. Wm. Harris, in company with Mr. S. W. Hill, spent a morning with the party at the Houghton mill, and at the purported new vein staked out by the mysterious "Dowsing rod." The Isle Royale mill contains a very remarkable machine, consisting of four enormous edgestone wheels made of cast iron, seventy tons weight in all, or eighteen tons on each wheel. The Osceola mine was visited, but on account of the breaking of a telegraph wire Mr. F. G. White was not informed of the party's visit. Mr. Jenney, however, explained the plans. The shaft houses are arranged for a large business. On account of the fineness of the copper

grains, rolls are to be used for crushing. At the Calumet mine Mr. Wright kindly gave the party the freedom of the mine and mill. Under the charge of Mr. G. G. Richards they made a trip to the mill, which is the largest at the lake, and has a very systematic tailing mill to check the work of the other. The clerk, Mr. John Camm, gave the party over into the hands of Captain Wm. Daniell, who took every pains to make the visit below ground interesting and instructive.

At the Phœnix mine Mr. M. A. Delano courteously gave the freedom of the mill and mine. He personally showed the mill, pointing out alike its strong and its weak points. Captain Wm. E. Parnell took the party down the mine, showed the difficult survey to locate the present incline shaft, and pointed out the false system formerly pursued of working the *ash bed* for itself; also the present advantageous system of working *mass copper* mainly, and *ash bed* incidentally. He showed quantities of mass copper in sight and explained how his prospecting work was gaining on his stoping. The Copper Falls was visited. Mr. Emerson entertained the party with a nice lunch and gave them free leave to examine and criticize everything. Mr. E. R. Parks, engineer, and the mining captain accompanied the party down the mine. The extensive *ash bed* workings were noted, and the slip in the ash bed visited. The masses are not quite so large as in the Phœnix, but there seemed many of them. The circular slime buddles in the mill attracted special attention.

The party next took a week of recreation on Isle Royale, which might have been well named the Island of Mirage, on account of its numerous atmospheric phenomena of looming and deception. The party were the guests of the Hon. S. W. Hill's camp on Fish Island which lies on the north shore of Isle Royale. In Mr. Hill's boats they made vigorous raids on the fish, and their zeal did not abate at his table. The workings of the prehistoric race of men around McCargoe's cove, which were shown by Mr. Davis, are very numerous and very interesting. The rock hammers brought seventeen miles, from the north of Lake Superior, in canoes are found by tons. The

country is rich in copper, and parties of prospectors under Messrs. Hill & Davis are now examining veins, intending to start works should they prove rich enough. Recently very encouraging indications have been met with.

At the Island mine Capt. George Hardie hospitably entertained the party. This mine is still in its infancy. The rock resembles the Calumet and Hecla, but the rule of the mine, that is where and when the copper will probably thicken, has not yet been ascertained.

At Silver Islet the party was given the freedom of the island by Capt. Wm. B. True, who took great pains in explaining matters. Captain Trethewey accompanied them, and Mr. James C. Hill, the clerk of the company, attended to their bodily wants.

The Lake Superior Copper region has afforded an excellent opportunity for the students of the Institute of Technology to study the very systematic process of ore dressing, which has grown up in the country by the efforts of Lake Superior men, and though its machines are like in principle to those used elsewhere, the plan is entirely peculiar to Lake Superior.

On returning, the party visited some of the iron mines in the Marquette region; — the Superior mine, the Cleaveland mine, and the Angeline mine; also the Negaunee and Deer Lake furnaces. On the way home they also passed a very interesting three hours at the Chester Emery mine. The expedition left Boston June 17, and returned July 25, time taken thirty-eight days; the average necessary expense per student being $110.00, or $2.89 per day. The B. & A. R. R. and the G. W. R. R. of Canada gave half fare. The steamers reduced their fare from $32.00 to $26.00 for the round trip ticket. The hotels also made deductions. One hotel charged 64 per cent. of its regular rate, another charged 80 per cent. The week at Isle Royale cost the students nothing; the party while there being the guests of Mr. Hill's camp.

Respectfully submitted,

J. M. ORDWAY.
R. H. RICHARDS.

STUDIES IN THE MINING AND METALLURGICAL LABORATORIES.

The experiments in the mining and metallurgical laboratory during the winter of 1873–4 were mainly tentative. Each machine and each furnace needs to be proved with every variety of ore that it is likely to be called upon to work, before the laboratory can be said to be an automatic department of the school.

During the past year several studies have been made. Mr. B. E. Brewster made some experiments upon silver lead ore from the Winamuck Mine, Bingham Cañon, Utah. His report has been condensed as follows:

These experiments were tried with a view to test the capabilities of the furnaces and to furnish certain data for future experiment. The Winamuck ore at the Institute is of two sorts. One a third class carbonate from the upper workings of the mine, and the other a sample of galena from lower down in the mine. The carbonate is in the form of powder, in which no minerals are distinguishable except a few small lumps of undecomposed galena, and a large amount of quartz in small grains. A quantitative analysis of a sample of the whole gives the following composition: —

Silicious Gangue,	34.01	per cent.
Lead,	33.78	"
Silver,	.21	"
Copper,	.33	"
Ferric Oxide,	12.07	"
Alumina,	1.50	"
Zinc,	1.21	"
Sulphur,	2.72	"
Carbonic acid,	6.60	"
Water,	7.10	"
Undetermined, arsenic, antimony, etc.,	.47	"
	100.00	per cent.

The galena is in lumps with very little fine stuff. There are several other minerals occurring with it of which the following were detected: Iron Pyrites, Sulphur, Zinc Blende, Quartz, Chalcopyrite, Blue clay, Tetrahedrite, Feldspar. Only a small quantity of Tetrahedrite was found, not more than two or three grams in looking over 225 lbs. of ore.

A quantitative analysis of a sample taken from 225 lbs. of the galena is as follows: —

SiO_2	8.56	per ct.	SiO_2,	8.56	per ct.
Lead,	49.42	"	Galena,	57.06	"
Silver,	.34	"	Silver,	.34	"
Copper,	.78	"	Copper pyrites,	2.27	"
Iron,	8.17	"	Iron pyrites,	14.87	"
Alumina,	1.70	"	Ferric oxide,	.63	"
Zinc,	8.33	"	Alumina,	1.70	"
Sulphur,	20.47	"	Zinc blende,	12.43	"
	97.77	per ct.		97.86	per ct.
Undetermined arsenic, anti'ny, water,	2.33	"	Undetermined,	2.14	"
	100.00	per ct.		100.00	per ct.

Experiment 1st. To Smelt Winamuck galena in the Reverberatory furnace by the Flintshire method.

This process consists of two parts; the ore is first roasted to convert a considerable proportion of the galena into sulphate and oxide of lead; and secondly, the heat is raised, causing the sulphate and oxide of lead to react upon the still remaining sulphide of lead, whereby metallic lead is liberated and sulphurous acid gas is disengaged. The method yields a slag very rich in lead, which is subsequently treated in a cupola furnace.

The following is an analysis of Flintshire ore.

Galena,	89.95	per ct.	
Zinc blende,	.99	"	
Oxide of lead,	5.15	"	Metallic lead, 82.71 per ct.
Lime,	.65	"	
Ferric oxide,	.29	"	
Alumina,	.13	"	
Carbonic acid,	1.62	"	
Insol. residue,	.85	"	
	99.63	per ct.	

The resulting slag contained 50 per cent. lead.

To apply this method to such an ore as Winamuck galena seemed rather hopeless, still it was thought that by taking more time a reduction to metallic lead might be effected; at all events it would show what the furnace would do. The furnace hearth is $4' \times 5'$ with a slope from all points to the tap hole. The following is the narrative of the experiment: —

Furnace fired at 9.15 A. M. with Cumberland coal. At 10.15 the furnace being at a dull red heat, a charge of 100 lbs. of finely powdered galena was introduced, the galena covered the bed with a layer $1''$ to $1\frac{1}{4}''$ deep; the roasting was continued until 4.30 P. M. A sample was taken every hour to show the rate of desulphurization. These samples were afterwards tested with the following results.

	Per ct. sulph.		Per ct. sulph.
Galena before treatment,	20.47	No. 4, after 5 hrs. roasting,	8.75
No. 1, after 2 hrs. roasting,	13.26	No, 5, " 6 hrs. "	7.65
No. 2, " 3 hrs. "	11.87	No. 6, slag after fusion,	2.30
No. 3, " 4 hrs. "	10.10		

The next morning fire was lit at 9.30 and was urged as much as possible. At 12.30 the charge had assumed a semi-liquid and an air blast was now put on under the grate, 20 lbs. sulphate of soda were added to aid in the fusion, 10 lbs. of scrap iron were added to separate metallic lead; but all was in vain. At 5.30 the firing was stopped and the charge withdrawn. The failure to produce any metallic lead was due to the fact that the ore contained just enough lead to make a flintshire slag and none to spare. The resulting slag was much the same as the Flintshire gray slag, containing, however, a little less lead.

Pb = 45 per cent.
S = 2.3 "

Experiment 2d. To smelt Winamuck carbonates and the rich slag from Expt. 1st, with tap cinder and a little galena in the cupola furnace.

The furnace measures eight feet from tap hole to feed door; the interior cross section measures twelve by eighteen inches. The tuyere in the rear is seven inches above the tap hole.

The blast is fed through a $\frac{7}{8}$ inch tuyere and is of a pressure equal to $\frac{1}{2}''$ of mercury. The fuel used was gas coke. In all furnace work of this character it is all important that the slag should be of such a composition that it may be melted easily and after melting to run liquid. Hence it is all important for the smelter to ascertain from the materials at hand, the proportions most efficient to produce a liquid slag, which shall not be so basic on the one hand as to choke the furnace with salamanders, nor so acid on the other hand as to become viscid and stiff as soon as it appears outside the furnace. The slag in this instance was planned to have

Silica,	30 per cent.
Ferrous oxide,	50 "
Alumina,	20 "

Which corresponds to the formula,

$2(Al_2O_3)\ 7(FeO)\ 5(SiO_2)$.

And the mixture used for each charge was: —

Carbonates,	25 lbs.	
Slag from Expt. 1st,	$6\frac{1}{2}$ "	
Tap cinder,	25 "	
Galena,	$3\frac{1}{2}$ "	
Coke,	8 "	= 2 shovels.

Narrative of the experiment: — A fire was lit the night before to dry and heat the furnace. In the morning put blast on at 9 A. M., first ore charge at 10.35; charged every fifteen minutes. At 11 A. M. the first lead appeared; from this time on the lead and slag were tapped every ten to fifteen minutes. The furnace passed through various vicissitudes during the day none of which were very encouraging. About 6 P. M. the furnace became hopelessly constricted, and on tearing down the front a salamander about ten inches in diameter of aggregated metallic iron was found. This result proves that the slag was too basic. However, the composition of the tap cinder was not perfectly known and this error is probably enough to cause the failure. This slag carried 6.33 per cent. of lead.

Experiment 3d. To smelt Winamuck carbonates and a

small proportion of galena with lead slag from Expt. 2d and so much tap cinder and lime as to produce a double silicate slag FeO, CaO, 2 (SiO_2).

This slag would contain,

Silica,	48.4 per cent.
Ferrous oxide,	29 "
Lime,	22.6 "

The proportions for the charge were: —

Carbonates,	25 lbs.
Lead slag,	25 "
Tap cinder,	1 "
Lime,	7 "
Coke,	½ hod.

The trial was a failure. It will be unnecessary to describe its details. The slag was so acid and viscid that it could hardly be made to run from the furnace. It seems evident from these experiments that basic slags will have to be used in this furnace. The radiation of heat is very large, while the heating power is comparatively small. Basic slags are much more fusible than acid ones.

Experiment 4th. To smelt a mixture of Winamuck carbonates and galena in the proportion of 2 : 1 by weight. Fluxes to be magnetic iron ore and lime, mixed to produce a monosilicate slag.

$3(FeO)\ CaO\ 2(SiO_2)$.

This formula would require,

Ferrous oxide,	55 per cent.
Lime,	15 "
SiO_2,	30 "

And an allowance also of iron to desulphurize the galena.

The charge used in the furnace was: —

Carbonates,	12 lbs.
Galena,	6 "
Magnetite,	12 "
Lime,	3 "
Coke,	8 " = 2 shovels.

Narrative of the experiment: — The furnace was warmed and dried by a fire the evening previous. The first charge of ore was put in at 10.35, charged every fifteen minutes. At 11.57 lead appeared. At 1 P. M. finding that the slag was too basic, the amount of twelve lbs. of magnetite per charge was reduced to eight lbs. By 2.40 P. M. having used this charge six times the slag became so stiff as to render it almost impossible to tap the furnace. Two lbs. of sulphate of soda were now added, and helped matters considerably. At 4.30 the charge was changed so as to contain ten lbs. of magnetite, and with an addition of ten lbs. of foul slag which was made during the early part of this run. The furnace was soon running finely giving a good ingot of lead and clean slag at every tap. This continued during the rest of the run. The material in the furnace stood at about 3′ 7″ deep. At 8.30 P. M. stopped charging. At 10.30 P. M. took off blast. Material in the furnace was 1′ 6″ deep, tore down the front and raked out the residue. The furnace was in better condition than after the previous run, there was a small scaffold on the back side. The slag contained 1.34 per cent. of lead. Unfortunately but a partial analysis of this slag has been made.

Silica,	34.27 per cent.
Ferrous oxide,	35.28 "
Lime,	7.10 "

This slag contained but 1.5 per cent. lead, and its composition differs largely from the above plan.

The old proverb "we learn by our failures," is doubly true of this laboratory. I think that any practical metallurgist will at once recognize the advantage to a student of a study like the one just described. Another sample of laboratory work is here given.

A silver lead ore worked by Mr. F. H. Jackson. This ore is from the 2d vein that is intersected by the Burleigh tunnel, which is situated near Georgetown, Colorado. The ore was examined for its mineral species. The following minerals were discerned: — Galena, coarse and fine grained; zinc

blende (black); pyrites, mostly granular; chalcopyrite; feldspar; mica; quartz.

The galena, zinc blende, and pyrites formed the greater part of the ore, the galena being by far the predominating mineral. From inspection of the ore it was evident that it would be advisable to separate the galena into one portion fit for smelting; the zinc blende into another to be treated by chlorinating roasting followed by amalgamation in a tub; and lastly the dust resulting from crushing, etc., which would contain too much galena for amalgamation and too much zinc for smelting. This dust it was thought might be treated successfully by gas chlorination, followed by a leaching with salt or hyposulphite of soda. The method of ore dressing had to be planned therefore to prepare the ore for three distinct metallurgical operations. The weight of ore taken was 476 lbs. 14 oz. It was at first sorted, making on the one hand a heap of pure galena, and such pieces as contained galena and pyrite, but in every case free from zinc blende. The other heap was made up of pieces containing zinc blende and other minerals.

(A.) The galena portion weighed 144 lbs. 14 oz.
(B.) The zinc blende portion weighed 331 lbs. 2 oz.

The portion (B) was crushed in a Blakes crusher set at $\frac{3}{8}$ of an inch, and sized with sieves and made ready for jigging. That which passed through a sieve of twenty meshes to the inch was saved in a separate portion, it being too fine for successful jigging. The sizes which were obtained by the sieves were

Grains which passed $\frac{3}{8}''$ sieve but remained on $\frac{1}{4}''$ sieve.
" " " $\frac{1}{4}''$ " " " " $\frac{1}{8}''$ "
" " " $\frac{1}{8}''$ " " " " $\frac{1}{20}''$ "

The jigging was performed in a sieve one foot in diameter suspended from a long wooden spring, the sieve being in a tub of water. The operation of jigging consists in placing the mixed ore upon the sieve; the sieve is shaken up and down, being kept under water at all times. By this means at every jerk downwards of the sieve, the ore particles are all of them

allowed to fall through water; the heavier invariably sink faster than the lighter. When the jerks have been repeated a sufficient number of times, the whole of the heavy ore will be found underneath while the light parts will be found on top. By this means an almost perfect separation of ore from gangue may be effected. Each of the above mentioned sizes was jigged by itself, for it is not desirable to treat all sizes together, as a large lump of a lighter mineral will settle as fast as a small lump of a heavier mineral. When the portion (B) was jigged four distinct layers were obtained. Gangue, blende, pyrites, and galena. In scraping out the sieve however, the division was made into two portions

(C.) Gangue, Zinc blende. and pyrites, 79 lbs. 2 oz.

(D.) Pyrites and Galena, 187 lbs, 2 oz.

Of that portion which passed through $\frac{1}{20}$ inch mesh sieve, the coarser part which remained upon $\frac{1}{40}$ inch mesh sieve was treated upon a Rittinger shaking table and yielded quite a clean separation of galena from zinc blende.

The results of this work may be tabulated thus

Galena smelting portion,

From hand picking,	144 lbs. 24 oz.
" the jigger,	187 " 2 "
" the shaking table,	10 "
Total,	342 lbs.

Zinc blende amalgamating portion,

From the jigger,	79 lbs. 2 oz.
" the shaking table,	12 " 15 "
Total,	92 lbs. 1 oz.

Dust for gas chlorination below $\frac{1}{40}$ inch in size, 42 lbs. 13 oz.

This investigation was not finished satisfactorily on account of lack of time.

The above will suffice to indicate the character of the work, and its value to a student whose profession will hereafter demand the solution of such problems.

Respectfully submitted,

ROBERT H. RICHARDS,

Professor of Mining Engineering.

THE INSTRUCTION IN MECHANICS AND MECHANICAL ENGINEERING.

President J. D. Runkle:—

DEAR SIR:—In the Department of Mechanics the methods of Professor Rankine's work on "Applied Mechanics" have been mainly followed, this having been used as a text book, together with my printed "Notes on Mechanics." The ordinary subjects of Statics, viz., the Composition and Resolution of Forces, and the Conditions of Equilibrium, were first taken up; subsequently the subject of Distributed Forces was considered, both as applied to determinations of centres of gravity and the internal stress of bodies.

A set of models illustrative of the latter subject in its applications to tensile, compressive, and transverse strength, and also the internal conditions as to stress of homogeneous granular masses, have been employed with decided advantage.

But little time was left for the subject of Dynamics, and this was devoted to a consideration of the most important of the laws governing motion, momentum, force, energy and allied subjects, such as Moments of Inertia, Radii of Gyration, etc. The instruction is given partly by lectures, partly by recitations and blackboard exercises, and partly by the computation of numerical and practical examples, which last forms an important feature of the work in this subject.

The progress of the class was quite satisfactory, only three students having been conditioned at the close of the last school year, all of them having subsequently made up their conditions at a re-examination.

A proper knowledge of Applied Mechanics being vital to all successful progress of the student in any of the Engineering Courses, it has been, and is, the aim of this department to so arrange the work and so give the instruction that they may have a direct bearing on those subjects considered in the professional departments which depend upon mechanical laws; and, moreover, to point out as far as possible, and enable the student to keep in view and understand the methods of making the applications of the theoretical topics presented for his consideration. The plan of the instruction, therefore, involves the discussion of the applications of statical and dynamical principles immediately after, and in connection with, the principles on which they depend. A few of these subjects are the following:

1. The methods of determining the stresses in the different parts of a structure; in beams and in columns under given loads; and the mode of distribution of these stresses in the single pieces; also the forces acting on the moving pieces of machines, such as connecting rods, wheels, shafts, etc., both in regard to the motion produced and the stresses acting in the pieces themselves.

2. Methods of determining the thrusts in arches, retaining and reservoir walls, etc.

3. Determination of the momentum and energy of moving bodies, either pieces of machinery or not, and other kindred subjects.

It is hoped by this means to so familiarize the student not only with the theory, but also with the mode of readily applying mechanical laws, that he may find in his Mechanics a ready tool with whose use he is familiar, and which he can apply with facility and judgment to any of the investigations he is required to make in his professional work, either at the Institute, or hereafter.

The adoption of the new scheme of studies last session could not at the time much affect, in this particular subject, the condition of a class as far along as their Third Year; but in the present year the three following consequences of the scheme promise to aid materially in carrying out more fully the plan already laid down.

1. The Calculus, instead of being studied contemporaneously with the Mechanics, is completed before the Mechanics begins; hence the student does not have his attention divided between these two serious studies.

2. The parts of the Calculus used in the Mechanics are already known by the students, so that they are not obliged to stop and devote part of the time that belongs to the Mechanics in studying the mode of performing the necessary Calculus operations.

3. The number of exercises, though not materially increased as a whole, has been made three per week instead of two, as heretofore.

These changes must inevitably aid in a decided manner the fuller carrying out of the above scheme. I would further suggest that it would be extremely desirable, whenever it is possible, and there are no special reasons to the contrary, that such subjects in the professional departments as depend directly on, and involve the applications of, mechanical laws, should be treated by the department at such times as the students are considering in their Mechanics the theories involved; also that experiments bearing on such subjects should, as far as possible, be made at the same time in the laboratories, as it is believed that approaching a subject at the same time from different points of view is conducive to a more thorough understanding of it on the part of the student.

Such an arrangement has been made in the department of Mechanical Engineering, and in whatever other department it should be found practicable to adopt such a system, it could not but infuse a new life into the interest taken by its students in their Mechanics, besides saving more or less a repetition and

review on the part of the professional department of the modes of applying the mechanical laws to the practical cases, before being able to proceed with the purely professional work depending upon them.

I would also submit that whenever the previous preparation of the students shall warrant the completion of the Calculus in the second year, and allow the Mechanics to be studied three times per week for the whole of the Third Year, the degree of completeness with which the scheme already laid down can be carried out will be even further increased.

The work done in the Mathematical part of the Mechanical Engineering Course during the last school year was as follows: in the Fourth Year's Class the subjects studied were Dynamics of Machinery, Strength of Materials, and Thermodynamics; in the Third Year's Class, Mechanism and Thermodynamics; in the Second Year's Class, Mechanism.

Professor Rankine's treatises on Machinery and Millwork, and on the Steam Engine, were used as textbooks, and the above subjects were taken up in the order followed in these works: thus in the Dynamics of Machinery the laws governing Momentum — Energy and Work of Machines and parts of Machines were first considered. Subsequently the subject of Friction, and the work used in overcoming it, the efficiency and counterefficiency of Primary pieces and of modes of connection in Mechanism were discussed, and also the subjects of Brakes, Dynamometers, Indicators, Flywheels, Governors, etc.

In the Thermodynamics the greater part of Chapters I, II, III, and IV, Part III of Rankine's Steam Engine were studied; the following being a part of the subjects discussed, viz: Thermometry and Calorimetry, Absolute temperature, Specific heat, real and apparent, Sensible, Latent, and Total Heat of expansion, evaporation and fusion, Efficiency of furnaces and boilers; Evaporative power of fuel, Total Heat of combustion of fuel and Draught of Furnace, Isothermal and Adiabatic lines, Potential and Thermodynamic functions, Indicator diagrams of jacketed and of unjacketed cylinders, Efficiency of steam in the

cylinders, Properties of Saturated and Superheated steam, etc., etc.

In the Strength of Materials Part III of Rankine's Machinery and Millwork was studied, and such explanations and illustrations given as seemed necessary for a full understanding of the subject. The Third Year's Class in Mechanism completed the greater part of Part I of the Machinery and Millwork; and the Second Year's Class took up the subjects of Cams, Connection by Bands, Linkwork, Reduplication, and Hydraulic connection. The same subjects are presented at the same time to the student in this and in the other three parts of the Mechanical Engineering course, viz., the Practical, the Graphical and the Excursional; and he is made to approach them from a different standpoint in each. This system keeps up the interest of the student in his work, and gives him a far greater degree of familiarity with it than he would otherwise acquire.

The instruction is given partly by lecturcs, recitations and blackboard exercises. But few written exercises and computations are required to be handed in in this part of the course; this belonging more particularly to the practical part of the course. Care is also taken not only to collect from Professor Rankine's other works whatever is said on any particular subject, but also to utilize all other available sources, in order to present to the class the simplest and clearest demonstrations.

Such models as the Institute is already provided with have been used with the greatest advantage, and indeed are indispensable. It is only to be hoped that their number may be increased as rapidly as possible. The progress of all the classes was very satisfactory; all the students who stood the final examinations having passed without conditions.

Very respectfully,

GAETANO LANZA.

REPORT OF THE DEPARTMENT OF MODERN LANGUAGES FOR THE YEAR 1873-4.

President Runkle: —

DEAR SIR: In the absence of any previous report of this department it is difficult to obtain a satisfactory idea of its past course and policy. For the following brief statements and impressions in regard to the year immediately preceding that under consideration, I am principally indebted to the tabular views in the catalogue and the examination papers.

1. *Brief review of the department for the preceding year.*

During the year 1872–3 French was taught in all the classes throughout the year, excepting in the second half of the Fourth Year. The same is true of the German, excepting the first half of the First Year. The number of exercises per week varied from one to four, rising to the latter number only in the First Year during the first half in French, and falling to the former number only in the First Year during the second half in German. The number of exercises per week, with these exceptions, varied from two to three. Taking this year as a basis, the number of exercises of an hour each a student would have during his entire course would be 270 in French, and 225 in German. These exercises were almost entirely in the form of recitations. As to the amount of time allowed or used outside of the recitation room for work, whether beforehand or afterwards, on these exercises, I am unable to obtain any exact data. What indications there are would lead to the con-

clusion that this was not very much nor very regular. The amount read, however, in both French and German, was considerable, amounting to 300 pp. or more in either language. The entire number of recitations a week varied from twenty-four in the first term to sixteen in the second. As a result the graduates have for the most part, I believe, been able to read easy French at sight, but as much cannot be said of the more difficult German. As to the accuracy and strength of the students' knowledge it would be difficult to make any statement.

With respect to the above, it should be remarked that the number of recitations, 495 in the regular course in French and German, is very large. Moreover those in German were disproportionately smaller than those in French, whereas they should be more numerous, in view of the much greater difficulty of the same and the greater time necessary for attaining the same degree of proficiency. If the impression be a correct one, that very little independent work was done by the student outside of the recitation hours, the results would indicate that such work is necessary for accuracy and strength in the practical use of these languages.

2. *Scheme for the modern languages at the beginning of the year* 1873–4.

At the beginning of the year 1873–4, it appeared that the time previously assigned to both French and German had been very much curtailed, owing to an action of the Faculty aiming at lessening the pressure of work upon the students, which had been found to be too great. On the basis of this half year as indicated by the tabular view, the entire number of exercises in the regular course would be in French 150, and in German 210, instead of 270 and 225 respectively as in the preceding year, or 360 for the entire course instead of 495 as before. Besides, it was expressly provided that no preparation should be allowed for one of the exercises, and only an hour for another. The diminished number of exercises would have sufficed, in itself considered, but the difficulty was that the students, excepting the First Year, were unable on account of the pressure of their profes-

sional work to devote any adequate amount of time to the work of the French and German.

The entire number of recitations per week in the regular course this term were 12 in French and 10 in German, counting the repetitions on account of division of classes. In the special Italian course there were 2, making in all 24.

3. *New scheme for the French and German, being a part of the general revision of the studies of the Institute.*

Before the close of this term it was found necessary to undertake a complete revision of the entire scheme of study of the Institute. This was very carefully and deliberately worked out and put into operation, so far as possible, the second half of the year. The provisions of the same, so far as it referred to this department, were as follows. (1) But one modern language is to be taken up at a time, and this finished before another is commenced. (2) Three exercises a week for two years are allowed to each language. (3) Two hours for preparatory or subsequent work are provided for each exercise.

(1.) In regard first to the time when one language can be dropped and give place to another. Inasmuch as French is required for admission, this would naturally be continued until finished, when German would be commenced and receive the length of time assigned to it. As the requirements in French at the first examination on this subject for admission were equal to about half a term's work in the school, this language would be finished by this class at the middle of the second half of the Second Year. The requirement for admission as fixed in the catalogue for the next class being about twice as much as above, this class would be through with its French by the middle of the Second Year, and so on in proportion as the French requirement for admission may be increased. In the second case the German would be finished by the middle of the Fourth Year.

(2.) In regard to the length of the course and frequency of the exercises. A smaller number of exercises per week than three, especially at the beginning, would, it is thought, fail of se-

curing such a concentration of the student's attention upon his work as is to be desired. This number, however, would secure that object and produce probably the best proportionate results, being at the same time consistent with the student's exercises in other departments. Three exercises a week for two years give a course of one hundred and eighty exercises. This number is smaller than that allowed the German the first half of the year in question, and much smaller than that allowed either language last year. It happens to be exactly the same length as the course in each of these languages at another prominent and well-established scientific Institution, except that there the time at the student's command for previous and subsequent work is somewhat greater. A course of this length prosecuted in the manner indicated should, it would seem, enable a student to translate ordinary French at sight, with a fair amount of accuracy and strength in dealing with passages of special difficulty. This would probably be too strong a statement for the German, whose construction is more involved, and which requires much more practice than the French. But although the time given it is no more than that given the French, it should be said that it is taken up after the student has had the training in language afforded by the latter course. It is to be understood that this scheme has reference principally to the regular courses for all students. The Science and Literature and optional classes would naturally be treated more or less differently. The former for instance, where the course in French and German is more of a literary and philological character, might have more time allowed them; while the latter, where the object is principally practice and the acquisition of a vocabulary, could pursue advantageously a course of two exercises a week without being called upon to do any outside work.

(3.) The final and perhaps most important point of this scheme to be considered is the time assigned for work outside of the recitation room. This has reference partly to the rapidity of the student's progress, but more especially to the character of the work done. A very considerable part of the recitation

room exercises, such as practice in pronunciation, learning new words, becoming familiar with forms, and practice in translation can be done as well by the student alone, after he has received specific directions with illustrations in regard to the above. An allowance of time therefore for work outside of the recitation or lecture room necessarily accelerates his progress to a corresponding degree. But of more importance than this is the consideration that the character of his knowledge is largely dependent upon the student's unaided work by himself. There is a strength in the knowledge and use of a language gained by working out a translation alone which can be gained in no other way. Thus the student is forced to decide why this must be so, and why it cannot be otherwise, either by searching for and comparing other similar cases or examining the law in the grammar. Besides, when for the sake of acquiring words and fluency in the use of the language, easy French or German is read to the class in the recitation room, the full and proper results of such an exercise are only secured when the student has subsequently gone over by himself what he has followed in the class room. But to require such outside work in the study of the languages is apt to be looked upon with suspicion, as it is so often misused for the memorizing of disconnected grammar rules, or even a too minute or extensive attention to the analysis or construction to the sacrifice of the thought. But when the time is legitimately used, as hinted at above, the bearings of the work are recognized, and there is no reason why it should not be agreeable, and not an irksome task. The ability to comprehend a foreign language with readiness and accuracy is an acquisition of no slight value, and in this as in other departments of science the value of the results is apt to correspond pretty closely with the work required in order to attain them. However much a proper method may facilitate the accomplishment of the object in view, much time and work is indispensable.

4. *General views in regard to the instruction in the modern languages.*

In connection with the above scheme it is desirable to con-

sider also by what general method the student can best pursue his study of a modern language. Shall it be (1) the rote or practice method, such as a child pursues in learning its mother tongue, or the similar so-called Ollendorff method; or (2) what we may call the *à priori* or dogmatic method, such as is generally pursued in the study of the dead languages; or (3) a mean between the two combining the excellences of both, while avoiding their defects. We think decidedly the latter.

For what is the object in view? It is to learn to *read*, with *accuracy* and *readiness* a scientific work in French or German. Accuracy and readiness, theory and practice, both are essential, but they must be in due proportion. To proceed as a child does in learning its mother tongue, although such a course if continued long enough would undoubtedly produce a satisfactory result, is neither necessary nor practicable. Developed powers of judgment and thought give him an advantage over the child, not only with regard to the point at which he can take up the subject, but also the manner of pursuing it. Why not take up at once the actual text and apply his powers of observation and the principles of induction, being assisted in learning the laws of the language both by the teacher and the embodiment of the same in the grammar. Talking is not his object, although conversational exercises will prove of assistance in making him familiar with the laws and idioms, and in learning words. Should he visit the country where the language is used, in which case alone he will have occasion to speak it, that facility will follow readily, as experience can testify. Facts also prove that he can enable himself to comprehend accurately and readily the page of a foreign writer, although he might not be able to hold a conversation in the same language. This is all he needs, and it is not consequently necessary to consider the more psychological than philogical or practical question, as to whether a person can read intelligently a foreign language, who cannot speak it or think in the same. But practically his other engagements are such that he cannot devote a large amount of time at frequent intervals,

as would be necessary if he were to learn another language just as he learned his own. Moreover, there is serious danger that this purely practical method, in itself considered, will fail of being a permanent acquisition, coming as it does from practice, and dependent upon constant practice, just as Americans, who have learned in a very short time to speak by rote the language of a foreign country, upon returning are deprived of their practice and soon lose their power of either speaking or reading. Practice in reading alone might not require so much time, but it would be equally open to the objection just mentioned.

Nor, on the other hand, is the method currently used in the study of the dead languages adapted to the end in view. That involves too much anatomical work, and fails to give the necessary practice and readiness in appreciating the thought of the author. It is open to the charge of studying the grammar, etymology and logic, too much, but the language, too little, which, though it might be defended with a purely educational end in view, cannot be where the object is a practical one. This system sacrifices the practice and favors the theory, the former favors the practice and sacrifices the theory.

But a mean between these two extremes seems best adapted to conduct the student most surely and expeditiously to his object, which is to read understandingly and readily. He should have the practice and attention to the thought of the author on the one hand, and on the other such a systematic knowledge of the main laws of the language as will ensure him strength and accuracy in interpreting its authors, and which being thus fixed in the mind will never be forgotten, though the practice should be intermitted. In a word, the student should from much practice acquire a practical readiness in appreciating the thought of the writer on the one hand, and on the other such a survey and comprehension of the structure of the language, as will make his acquisition a permanent one, and one enabling him to meet with strength serious difficulties of interpretation.

In practically carrying out these views, the actual text of the foreign language in some form has been presented to the student from the outset for his practice and study. In connection with this the forms have been studied and practiced, so also the principal laws and usages of the language, in the progress of the student's course. Consequently grammar, or a systematic embodiment of these forms and laws, has been a constant subject of study. Much reading gives the requisite practice, while a careful attention to the grammar or laws of the language not only facilitates the acquisition of the same, but ensures the student accuracy, and the permanency of this acquisition. But it is very important practically to know what is understood by the study of grammar. If it means learning a number of technical, obscure expressions, or the memorizing of a body of rules or observations not in immediate connection with the living text, but which it is intended to apply to that at some future time, then it is not strange that it should be to the student a very unwelcome work, and its study seem a very irksome and unprofitable task. But if grammar means a regular induction of the laws of the language, resulting from the observation and comparison of individual cases and their systematic arrangement, then its study affords a satisfaction and sense of mystery to the student, and he is as much interested in it as he is in the laws of any science. He realizes that there can be no accuracy without these laws, and that, from the fact that he can comprehend them more quickly than the child and apply them with less practice, he progresses far more rapidly in acquiring the language. The aim has been, accordingly, constantly and regularly to call the student's attention to these laws as the text has presented them, and to use the grammar as a reference book for a fuller statement, and also a permanent one for him to refer to at his pleasure. Much importance has been attached to dictation exercises as a means of presenting these laws and affording practice on them, also of learning words, idioms, and the general spirit of the language. They have accordingly been a frequent and regular part of the work.

In addition to the semi-annual and annual examinations, there have been intermediate examinations of an hour each on the amount gone over the preceding month. It is believed that these have been of much value, in giving the student a definite indication of his progress, while they also afford practice in writing translations, and precision in the expression of his knowledge.

After considering the shortest way, so far as is consistent with strength, permanency and accuracy, of attaining to the ability to read readily a foreign work, the thought naturally arises, what is the value of this course of training as a means of general culture. Were the latter the direct object, some modifications would perhaps be desirable, but as it is, there can be no doubt that such a course, being of a methodical nature; and having to do with the written works of other people, must exert much influence in the direction of a liberal and general culture. This consideration presents an additional reason for allowing this work an adequate provision of time, and bestowing upon it especial attention.

5. *Work done in the several classes during the year.*

FRENCH. *First Year.* In addition to exercises in especial connection with Otto's Grammar, the class read during the year fifty-nine pages in Otto's Reader and thirty-five pages in Corinne. There were three exercises a week, with two hours for preparation during the second half. *Second Year.* The French was confined to the first term, at the rate of two exercises a week, no preparation being allowed. Seventeen pages in Corinne were read. *Third Year.* The French was also here confined to the first term, at the rate of two exercises a week, with one hour for preparation on each. The "Atala" of Chateaubriand was read, or one hundred pages. In the *Fourth Year* there was no French.

GERMAN. *Second Year.* There was no German in the First Year, but the Second Year commenced this study at the rate of three exercises a week. In the second half of the year the class had two hours' preparation for each exercise, in the first half there was often no time for this, and the amount was

in general small and irregular. In addition to dictation and other exercises, fifty pages in Whitney's Reader were read. *Third Year.* Selections from German ballads, also Heyse's "Die Einsamen," eighty-eight pages. There were also dictation exercises. *Fourth Year.* Besides a few German ballads, Goethe's "Egmont" was read, making one hundred and forty pages. The class continued the study optionally through the second term with the Science and Literature class.

In addition to the above, in which all of the regular and some of the special students participated, five members of the Science and Literature and Philosophical departments pursued in the Third Year, second half, an advanced course in French, reading three plays of Molière (149 pages) with regular exercises in dictation, and the translation of longer extracts from English into French. Members of the same department in the Fourth Year, continued during the second half their German, reading the last three acts of "Egmont".

There was an optional class in Italian during the year composed of six Fourth Year students. Two hours a week were assigned to it, and the subject pursued in such a manner that no outside work was required. It would seem advisable to urge students to go farther in French and German rather than take up Italian or Spanish, in which they can at best get only an introduction. But for those, who for special reasons, as students in architecture desiring Italian, or those in engineering expecting to go to Spanish-speaking countries, the best arrangement would seem to be, to have classes in these languages on alternate years open to students of both the Third and Fourth Years. That would enable each graduate to pursue a course in one or the other.

The time assigned in the second half of the Fourth Year to a course in the Science of Language, for students in the departments of Science, and Literature and Philosophy, it was impossible to utilize for want of time on the part of instructors. It is hoped that so valuable a course may be carried out the next year.

The whole number of exercises per week during the first half

year was twenty-four, during the second half twenty-three. Eight of these exercises in the first half, and six in the second half were repetitions, owing to the division of the First and Second Years.

6. *The regulation requiring French for admission.*

The regulation making French one of the requirements for admission was first put into operation at the commencement of the year of which this is a report. The amount required was "The first nineteen lessons of Otto's Grammar," that is, the elements of the language as far as regular verbs, with some practice on sentences illustrative of the same. This would be equal to at least half a term's or two month's work in the Institute. This requirement was poorly answered. The class at the beginning numbered seventy-nine, of whom thirteen had never studied French at all. The average mark in French of the whole class at admission, not including ten who had advanced much farther than the amount required, was somewhat below fifty on a scale of one hundred. There were thus three distinct divisions in the class, each demanding different treatment by themselves. The ten students advanced in French were excused entirely for the First Half Year. The thirteen who had never studied the language at all should have been enabled by more frequent exercises, and by reciting by themselves to catch up with the class, which could have been easily done by the semi-annual. But means of instruction failing for this, it was necessary that the whole, thus unequally constituted, should go on together, to the disadvantage of both, neither receiving the treatment best adapted to it. It is especially to be recommended that there should be in future such a separate class, at least until the requirements are better responded to.

The amount required in French the following year was: "Pt. I of Otto's Grammar, and the first twenty-five pages of Bôcher's Reader, or their equivalent." This is probably rather more than twice as much as the amount required at the first examination, and rather more than half a year's work at the Institute. It is to be hoped that it will soon seem feasible to increase this amount, so as to include a knowledge of the main principles of

ford profitable texts for such reading, although strict scientific treatments of subjects, especially in German, should be taken up by the students in the several departments with the help which they would receive from their Instructors and laboratories. Such a course should come at the conclusion of the regular one, when students are able to read at sight, even though hesitatingly, easy French and German. The best place for that in French would be in the Third Year, or better, in the Second, should that not be too much crowded; and for that in German in the Fourth Year. This course might consist of two exercises a week, no preparation on outside work being required or expected, and it being optional with a student, according to the time he may have at his disposal, to take it up or not, it being understood, however, that if he do begin he is to attend punctually, and pass the usual intermediate and annual examinations.

With arrangements as suggested above, the Science and Literature, and Philosophy students, would have the entire Third Year for an advanced course in French, and the Fourth Year for an advanced course in German. They would also have, as at present, the Second Half of the Fourth Year for the course in the Science of Language, intended to consist of familiar presentations and discussions with regard to the nature of language, its life and growth, the place its study occupies among the sciences, the separation of languages into dialects, the characteristics of the great families into which human speech is divided, and, finally, the question of the origin of language; these subjects being considered as much as possible with reference to the English, and illustrated by examples from the same.

The Italian and Spanish optional courses would continue as above indicated.

With expressions of sincere appreciation, Mr. President, of your constant and very valuable support of the management of this department the past year, the above is

Respectfully submitted.

C. P. OTIS.

THE INSTRUCTION IN INDUSTRIAL AND PHYSIOLOGICAL CHEMISTRY.

President Runkle: —

DEAR SIR: — As the number of our students has increased from year to year, the repeated demands for more room for chemical manipulation and analysis, and for metallurgical work, have been but insufficiently met by extending the laboratories so as to take up all the available space in the basement of the building. Other departments have also felt the need of an extended area, and in this continual struggle for space the less elementary branches have been compelled to yield. Hence the subjects which come under my special charge, industrial and physiological chemistry, still lack a local habitation, and many long felt wants remain unsupplied. But we invite students in advanced and special chemistry, and in order to keep up the rank which we have hitherto held among schools of science, it is important that laboratories should be established for the instruction of such students. For instruction and for research in chemistry, as applied to the arts, we should have facilities for operating on pounds of materials instead of grains, and there is needed apparatus similar to what is actually in use on the large scale. One who has worked only with test tubes, watch glasses, beakers, platinum crucibles, and small gas burners, is ill fitted to make such practical experiments as are required for the improvement of manufactures, and he necessarily feels much at a loss when brought in contact with the operations of real life.

There should be a *Laboratory of Industrial Chemistry*, affording room to work with tubs, stoneware jars, bag filters, large retorts, furnaces, and steam kettles. Connected with it there should be a *crystallizing room*, cool, and free from dust.

Such a laboratory is not for the industrial chemist only. Students who have to engage in special researches, whether practical or purely scientific, often find it necessary to prepare in the first place the chemicals required, for they are not to be found in commerce, or the shops afford them of unsuitable quality. The laboratory of analysis is no place for such manufactures, and lacks apparatus suitable for making the quantities required.

He who studies the proximate analysis of organic substances, or the synthesis and the metamorphoses of carbon compounds, must operate on comparatively large amounts of material, and on account of such needs, at least one room should be set apart as a *Laboratory of Organic Chemistry.*

Methods of analysis, synthesis, and transformation, have been latterly coming much into use, which involve the heating of substances in closed tubes and under high pressure. Of course there will sometimes be explosions, which not only scatter glass at random, but also diffuse suddenly through the whole room unpleasant or noxious vapors. Such things must needs disturb the equanimity of students quietly engaged in ordinary analysis, and the rapid and thorough ventilation which is suddenly called for, proves inconvenient where a large number are busy with nicer operations. The good of the greater number must therefore be sacrificed occasionally unless there is a special *room for high pressure experiments.*

The chemist who is restrained by wooden floors and tables from using combustible fluids finds the paths of investigations very much hemmed in, and longs for a vaulted room in which he can distil a few ounces of ether or benzole without watching his retort every moment with a hydrant hose in hand. *A fire proof room* prevents such anxiety, and much waste of time.

A special *room for gas analysis* should be added to the ordinary analytic laboratory.

That part of chemistry which relates to the growth of plants and animals is by no means of subordinate importance. And it has been felt that a professedly liberal course of education must be incomplete when physiology and biology are left out of account. Therefore in rearranging our courses of study, it was deemed proper to include botany and zoology as in themselves useful and as laying the foundation for that higher branch of chemistry which relates to the vital operation of living organisms. Hitherto the instruction in all these branches has been given by lectures or recitations, with the help of such specimens as can be conveniently handled in the class-room. But all science teaching is defective, which does not take in laboratory or field work on the part of the student himself. Experiments in germination, fermentation, respiration, diffusion, assimilation, and the like, need facilities for the exact and continued regulation of light, heat, moisture, and surrounding media. *The Physiological laboratory* then must have its peculiar arrangements differing greatly from those of the work-rooms already mentioned.

In the study of animal and vegetable chemistry much use is made of the microscope and the spectroscope. *An optical room* and an *apartment for dissections* are, therefore, essential adjuncts of the physiological laboratory.

If any one fails for the moment to understand why the chemist should extend his studies into the domain of Natural History, let him consider how many phenomena, which fifty years ago were set down as simply owing to some abstruse chemical action, are now found to be intimately connected with the development of cryptogamic growths. Let him remember, that in the examination of natural waters with reference to domestic use, the microscope often makes important revelations when chemical analysis fails to give satisfactory indications. Let him reflect that in studying the adulterations of food, drugs, textile fibres, and so on, the microscope is indispensable. So there are many matters that a chemist may be called to report upon, which are extra chemical and which the mere chemist is incompetent to investigate. It is indeed true, that in looking the

world over, we very rarely find physiological laboratories connected with schools of science. But how few years is it since even physical laboratories came into existence; and yet, who would now think an institution for scientific teaching to be complete without a physical laboratory? I believe the time is not very remote, when there shall be a like feeling with regard to the physiological laboratory.

A much felt want is that of a *working library room*, light, dry, airy, and clean, in which may be gathered books of reference, monographs and details of researches in chemistry, biology, microscopy; and this room should be provided with tables for writing and drawing, and with racks for charts and diagrams. The chemical department has, at present, no fit place for the few books and periodicals which we possess, and it can offer no shelves on which the Professors may place often consulted works from their own private collections, without fear of injury.

Shall I weary you by going on to say, that the use of class-rooms in common with other departments admits of no special adaptation to our particular requirements and gives little opportunity to prepare for lectures which should be enlivened by the exhibition of specimens, drawings, or projected images of actual tissues?

Excuse me for reminding you how straitened we are for room, when you call for a report on condition and progress. As to what has been accomplished during the past year, I can only say, "we have left undone many things that we ought to have done" and have done simply what we could. In respect to industrial and physiological chemistry, and botany, without even asking or receiving an appropriation we have gone on providing out of limited private means what was needed for the daily instruction, and have been gradually securing apparatus, specimens, charts, and books with reference to future work, hoping that the time will come when there shall be places for these things and room to work in.

Respectfully yours,

JOHN M. ORDWAY.

THE DEPARTMENT OF PHYSICS.

President Runkle:—

DEAR SIR:—Since the presentation of the last Report of the Physical Laboratory several important changes have been made both in its organization and in the facilities offered to the student. With the establishment of Physics as an independent Department, a Four Years' course is offered to a student who wishes to make a specialty of this subject, either to teach it, or for its applications. Like the Departments of Philosophy and Science and Literature, the course is also designed for those wishing an education of a less professional nature, but unlike them, the scientific studies are rendered more prominent than the literary. The exact course of study offered is detailed in the Catalogue and need not be repeated here, but it will be noticed that it combines most of the studies, not of a strictly professional character, of both the Engineering and Chemical departments. It differs from them mainly by the introduction of several special courses, including Photography, Lantern Projections, Electrical Measurements, Microscopy, Spectroscopy, and other advanced physical work.

The exercises in Physics given to all the students during the Second and Third Years are substantially the same as before, and it is not probable that any changes will be made in them except in details. All the lectures on general physics will now be given during the Second Year, instead of partly in the First Year as heretofore, and both the lecture and laboratory courses have been improved by the purchase of additional instruments.

Prominent among the latter are a Holtz machine and Induction coil, the want of which has heretofore been seriously felt.

The exercises in Photography consist in part of lectures, giving the theory and description of the most important processes and their applications, and practical exercises in which each student shall perform the whole work of taking photographs himself. A student can become a really skilful photographer only by long practice, but in a short time, if properly taught, he may obtain very good results and will be saved much time and money if he begins his work in the presence of some one who can point out his errors, and show him how to correct them. Otherwise, he may simply obtain poor pictures and be unable to decide what is the difficulty. Students will be taught to take both negatives and positives, special attention being paid to the former as the basis of almost every photographic process. They will then learn to take positives on glass suitable for projection in the lantern, and paper prints. As subjects they will employ mainly such as have a scientific value, as drawings and apparatus, and later, microscopic objects, spectra and other more difficult objects.

A course of Lantern Projections was given last year with results that justify its introduction as a permanent part of the course. The theoretical principles involved are given in the form of lectures, and each student then learns to perform the various experiments with the lantern, such as projecting photographs, chemical and electrical decompositions, opaque objects, spectra, using the vertical lantern and other applications of this most useful instrument. The method of making the calcium and other brilliant lights is also taught, and the method of measuring their intensity photometrically. The aim throughout is to enable the student, if required to deliver a course of lectures, to illustrate them fully by the lantern.

Another course tried for the first time during the past year is that entitled Advanced Physics. The object of this course is to supplement the other exercises and supply a place where any matter which a student should know may be properly in-

troduced. Its special object is to furnish the information ordinarily required by a scientific man from societies and periodicals. This want is met in some institutions by scientific societies among the students, but the objection to them is that a portion only of the students are in general interested, and of them most of the work is generally done by two or three. Moreover, although they may be started with much enthusiasm the interest often flags, and they are neglected for the regular studies of the school or for other duties. In the present case on the other hand attendance is required, as at any other exercise of the school, and special subjects being assigned to each student, all take part. During last spring a series of exercises of this kind was held, and eight students took part in them. One of the class was each time asked to act as Secretary, and took notes which he afterward copied and read at the beginning of the next meeting. Another student was then appointed in his place, and their notes form a permanent record of the work done. The meetings were attended with great regularity and the interest was well sustained. Some of the papers were original, but in many cases a subject was assigned to a student on which he prepared a paper, and presented it to the class. All the papers were illustrated, as far as possible, by experiments prepared by the student, who in some cases, also made the apparatus.

Among the papers were the following:—

Forms of Water in Clouds. Mr. F. H. Very.

Sternberg's Heat-registering Apparatus. Mr. S. J. Mixter.

A Fire-escape. Mr. C. F. Howard.

Pendulum Curves. Mr. C. A. Morey.

Zöllner's Horizontal Pendulum. Mr. T. H. Sampson.

Self-registering Barometers. Mr. S. J. Mixter.

Artificial Flight. Mr. C. A. Morey.

An Optical Dynamometer. Mr. W. O. Crosby.

Divisibility of Matter. Mr. S. J. Mixter.

Lippman's Capillary Electrometer. Mr. T. H. Sampson.

An improved Phonautograph. Mr. C. A. Morey.

During the past autumn a partition has been erected along the further wall of the Laboratory and small rooms thus formed for some optical and electrical experiments which are best prepared in the dark. This change is found to be a great improvement and to add materially to the available space. It is a step in the direction long advocated by the writer of employing a number of small rooms, instead of one large one for a physical laboratory. The manuscript of directions for performing a number of electrical experiments has been prepared, and through it much work has been done by the special students in physics in the measurement of absolute electrical resistances, currents and electromotive forces. An admirable practical application of this work has occurred in the tests now in progress of a large magneto-electric machine loaned to the Institute by its maker, Mr. M. G. Farmer. It is greatly to be desired that this machine may be secured permanently for the Institute, as its value would be very great in many ways. First, it would furnish a current of electricity of sufficient magnitude to produce an intense light which could replace the calcium light and might be used for lighting the large hall. Secondly, it opens a broad field of experiment for the students in almost every branch of physics. In mechanics it affords an extremely easy method of altering the amount of work done, and thus affording a very convenient subject for test by the dynamometer; several interesting questions in heat are also opened, especially with reference to the heating of wires traversed by the current. In light not only does it bring the electric light within convenient reach for daily experiment, if desirable, and of photometric and spectroscopic examination, but by an incandescent wire it furnishes a constant source of light, which opens quite a new field in photometry. Again in electricity and magnetism the value to the student of such a current constantly in readiness can only be estimated by those who have had occasion to employ powerful batteries for similar purposes.

The want strongly urged in previous reports, of some form of motor in the laboratory, and so generally supplied in other

similar institutions, is still felt with ever increasing urgency, and seems to demand immediate action. The simplest solution seems to be to keep one of the engines, now in the building, constantly running and letting the escape steam pass again into the circulation. The loss of heat would then be very small, being only that converted into work, and that lost by conduction. A countershaft should be run the whole length of the building, and the various departments could thus have power constantly available. Running a second countershaft across the physical laboratory, power could be carried by cords to any part of the room. If this was done, many instruments like the Holtz machine and stroboscope could be run continually and regularly, while several important experiments, such as the measurement of work and power would be easily available to the student.

Some problems in Astronomy have so important a bearing on affairs of every-day life, that every well educated man should be able to solve them. For instance, the determination of the latitude and longitude, of the time, and the direction of the meridian. It is therefore proposed to introduce some experiments of this kind into the course of Physics and to let the students determine these quantities by the sextant and transit.

During the past autumn the students in physics were taken to the works of the Howard Watch and Clock Co. at the invitation of Mr. J. Hamblet, and to the rooms of Welch and Andres Magneto-Electric Telegraph Co. at the invitation of Mr. Andres. Both excursions proved both interesting and instructive, and it is hoped that many similar excursions may be carried out when the weather becomes warmer. Several problems have been assigned to the students in designing apparatus, and this is made an important feature of the examinations. The demand for teachers of Physics would seem to justify the increasing number of students who are preparing themselves to fill such positions.

All of which is respectfully submitted.

EDWARD C. PICKERING,

Thayer Professor of Physics.

DEPARTMENT OF ENGLISH AND HISTORY.

President Runkle:

During the past and present years I have continued my efforts to bring my work within a manageable compass, and to give my instruction the form that would best meet the actual wants of my students. As the experience of each new year defines more clearly the distinctive character of our School, it becomes easier to determine the limits of each department. We are not a University, and cannot undertake the teaching of general subjects on a university scale. Our limited resources forbid the attempt to occupy a wider field than that which strictly belongs to us, namely, the sound training of young men destined for technical professions or for active business life. For the present, moreover, as I have before had occasion to point out, the imperfect preparation of our pupils compels us to keep the element of general study within even narrower limits than fairly belong to it, in order to secure, without detriment to the student's health, the amount of attention to technical study which is absolutely necessary to justify us in conferring our scientific degrees. While the standard of preparation for our school is undoubtedly rising, no sudden change can be effected through the influence of rigorous entrance examinations. We are in the midst of a slow-moving revolution in Education which will, sooner or later, make elementary English and scientific teaching what it should be; but for us to set our standard of admission much above the present teaching-capacity of the schools is either to put a premium upon

cramming or to deprive ourselves of students. Any industrious young man of sixteen or seventeen, of good capacity, and with such an amount of mathematical knowledge as will enable him to master our scientific course, and such a training in English studies as the schools are competent to afford, has a good right to claim access to the opportunity our school furnishes to qualify himself for a calling which requires technical preparation, without being held to the necessity of conforming to all the requisitions of an ideal scheme of Education, which it is impossible at present to realize.

Our scheme of *general* instruction must therefore be limited for the present, both by the limited attainments of the pupils, and by the very limited amount of time at their disposal after deducting that required by their professional studies. An attempt was made last year to remedy the difficulty of overwork by reducing the amount of time to be devoted to each separate study, while the original multiplicity of obligatory studies was retained. Experience soon showed that, though the evil of overwork was perhaps diminished, yet the reduction in the time assigned to many of the non-professional studies was so great as to leave it an open question whether the result produced in them was worth having. Compulsory attendance in non-professional work on the part of students already overtasked with professional study answers but little purpose, even when the will of the student is ever so good to profit by the instruction. It is far better, both for health and mental discipline, that the number of subjects should be diminished, and thus a reasonable amount of attention secured to those that remain. To make the English and historical instruction more efficient, I have therefore proposed—and the proposal has been adopted—that for regular students an option shall be given between the English and History and certain other general studies, and that the student shall be held to an examination only in such general study, or studies, as he chooses, liberty of voluntary attendance on the other general courses being at the same time granted to all students who have the inclination and can

find the time. Thus the abler and better prepared students may avail themselves of the opportunity to pursue a wider range of general studies, while the slower and worse prepared, by being relieved from compulsory attendance on so many non-professional lessons, will gain sorely-needed time for their strictly professional work. The instruction in general subjects will also gain the advantage of being relieved of a dead-weight of overburdened or unwilling attendants. The arrangement need not be considered as more than temporary. As the quality of the preparation brought up to us by candidates for admission improves, a larger element of general study may again be required of professional students.

This change of arrangements will not preclude the attendance of any student on the literary and historical lectures who has time enough for that, but not time enough for more. And I think that in literary and historical instruction mere lectures may be made of great value in organizing the student's miscellaneous knowledge, and giving system and direction to his miscellaneous reading. But attendance on them should be purely voluntary, and no farther requisition should be made in the way of examination than, perhaps, the handing in of a brief set of notes at the close of the course. It is absurd to expect from them the same results as from regular and systematic study. On the other hand, as the change is likely to give me a smaller body of students who will have time for work, I desire to state briefly my view as to the proper nature of that work. The question becomes more important, in consequence of the increasing number of students in the department of Science and Literature, who, not being candidates for either of the technical degrees, are expected to devote a larger share of their time to general studies.

It is obviously impossible for a single instructor to embrace in his instruction the whole of fields so wide as those of Literature and History. The mere reading of manuals and compends is *not* the study of Literature and History, but a bad and barren way of studying Biography and Chronology. Literature is

really studied where authors are really read, and if History can be taught at all, it can only be by some method which will teach the student not so much History as how to read History. For a teacher whose time is limited that object can best be accomplished by selecting some definite period, and arranging a system of reading and study on the part of his pupils, which shall bear some resemblance to the system of physical research and experiment pursued in the laboratories below. A library is the working-laboratory of the student of Literature and History, and the chief aim of the instructor should be to teach the art of handling and using books. So far as the object of making the student into a writer is aimed at, that cannot be done by setting him merely to the study of rules in the rhetorics but by turning him into the literary laboratory, there, in the closest connection with all his study of the writing of others, to practise writing himself. And where, as in the present case, the instruction in Rhetoric, Literature and History falls to the charge of a single teacher, it is obviously better to combine these subjects together as closely as possible rather than to separate them widely from one another by too careful attention to formal divisions.

The question as to what portion of History and Literature is best suited to be the subject of research and investigation by students in such a school as ours, can hardly be open to doubt. However desirable, as a matter of general culture, it may be for the man of business to be familiar with the whole record of the past, it is *essential* that he should understand the world he is to live in, and security had better be taken in school that he study that. I would therefore begin my course of instruction with the study of the present condition of things, and thereby supplement, as far as possible, our students' insufficient knowledge of civil and political geography. And it seems to me eminently suitable in such a school as ours, that special attention should be given to the statistics of Commerce and Industry, and to the history of those Arts and Sciences whose principles are the subject of study in other departments of the school.

The study of the present political, social and economical condition of the nations would naturally lead back to that of the events of the immediate past out of which that condition has arisen. The period of history beginning with the middle of the last century, includes several series of events which are specially adapted to be the subjects of extended investigation by students like ours. On the economical and industrial side it includes the whole story of those remarkable labour-saving inventions and of the application to them, as well as to locomotion, of the motive power of steam on which has arisen the vast fabric of modern commerce and industry, as well as the history of the wonderful growth and expansion of modern physical science in all its departments, while on the political side it embraces the story of our revolt from the mother country and the building-up of the republican institutions under which we live, as well as the outbreak of that great European revolution which followed, and a knowledge of the early stages of which is so essential to a right understanding of the present political condition of Europe. And further, this period includes the advent of a new era in literature in the appearance of that generation of writers who immediately preceded our own.

If I am right in the principle that the best method of studying literature is to read books, and the best method of teaching History is not to waste time on wide surveys and barren generalizations, but, by confining the student's attention to the detailed study of a definite period, to teach him how to investigate for himself, no period could be better suited to such a purpose than the one I have described. There is also this great advantage in teaching modern History and Literature, that while, to excite interest in the remote past, time, leisure and the cultivation of a special taste are required, no difficulty is found in interesting young men who are about entering upon the duties of active life either in the serious interests of the present or in the events of the immediate past.

But the study of History, if it is to be productive of any practical results, must be accompanied by, or must lead up to

the study of Political Science on the one hand, and of Economic Science on the other. The lectures on History are followed by a course on Law and Government in the form of commentaries on the U. S. Constitution, and a course on Political Economy accompanying the reading of a manual. These, for students in Science and Literature and for all regular students who enter this course for work, are accompanied by the collateral reading and writing described above.

As it is obviously useless as well as impossible to frame distinct courses for different sets of pupils, it will be seen that in my instruction I have to keep in view three sets of students; 1st, the regular students who can only attend lectures without work; 2d, regular students who elect to do work in connexion with my lectures; and 3d, "Science and Literature" students who have time for a larger amount of work. To meet the wants of the last, I organize small special classes, meeting in my library for supplementary reading and study. This has proved so interesting both to teacher and pupils that I propose to increase their number as far as time allows, and I see no reason why, under proper restrictions, volunteers from the regular classes and special students from other departments should not be admitted to them, without regard to the years in which they are classed.

Specimens of written work are herewith presented; among them elaborate papers on France and Russia by Messrs. R. C. Ware and S. H. Wilder, graduates in the department of Science and Literature, and one on British India by Mr. F. C. Bowditch, a special student in the department.

I have to report a uniformly excellent spirit in my department. I have never lacked interested and attentive hearers, and the conduct of the students in lecture-room and reading-room has been unexceptionable.

All which is respectfully submitted,

W. P. ATKINSON.

DEPARTMENT OF MATHEMATICS.

To the President: —

The instruction in this department now conforms to the new arrangement of studies contained in the catalogue. In consequence of this change, what was formerly a three years' course in mathematics is now concentrated within two years and two months. The number of exercises in the entire course remains unchanged, but instead of the former unequal distribution, there is now a uniform number of three exercises per week throughout the course. By thus completing his mathematical studies earlier in the course, the student is less embarrassed in those departments where this knowledge is applied.

Even more might be accomplished in this direction, if our students entered better prepared. Fully half of the First Year is now occupied in a review of branches which are among the requirements for admission. A higher standard of mathematical instruction in our preparatory schools will alone enable us to dispense with this review. A marked improvement in this respect is already apparent in some of the schools located near us, and if all our students before admission had the advantage of equally thorough instruction in mathematics, the course in this department would be materially strengthened. But when we take into account the character of the average instruction in mathematics in the high schools, where the majority of our students receive their preparation, it is evident that we cannot, at present, assume that thorough knowledge of algebra and geometry which will allow us to entirely omit these branches from our course. It is hoped, however, that at no distant day we shall attain this very desirable object, and that our students will complete their course in pure mathematics at the end of the second year.

GEO. A. OSBORN,

Prof. of Mathematics.

ABSTRACTS OF THESES PRESENTED BY GRADUATES OF 1873-4.

The following abstracts of the theses presented have been furnished either by the departments, or by the authors.

DEPARTMENT OF CIVIL ENGINEERING.

The students in Civil Engineering, of the class of 1874, were required to present as theses, designs for a single track railroad bridge, 192 feet in length. They were divided alphabetically into five parties of three each, and a different form of truss assigned to each party.

Of the fifteen students in the class, two were not candidates for a degree, two did not succeed in passing the examinations, and one has failed to hand in a thesis. The ten remaining, being those recommended for graduation, presented theses as follows:—

Herbert Barrows, a Post Truss; Wm. T. Blunt, a Post Truss; George E. Doane, a Double Warren Truss; Joseph S. Emerson, a Linville Truss; Elliot Holbrook, a Linnville Truss; Aechirau Hongma, a Warren Truss; Charles P. Howard, a Warren Truss; Herbert B. Perkins, a Murphy Whipple Truss; Edward S. Shaw, a Murphy Whipple Truss; Arthur W. Sweetser, A Murphy Whipple Truss.

The general treatment of the subject of these theses was necessarily nearly the same in all. A description of the particular truss is given, and its peculiarities pointed out. Next comes a discussion of the method of finding the shearing forces

and bending moments acting at different sections of the bridge, followed by a determination of the stresses upon the upper and lower chords, the struts, the main ties, the counter ties, and the connecting pins. The size that these members must have in order to sustain safely the stress upon them is then computed. The floor beams are next considered and the size fixed. The horizontal strain at top and bottom is also determined. Lastly, the weight of each member of the bridge is calculated, and the total weight of the bridge ascertained.

The drawings accompanying each thesis are two in number, and give a view of the finished structure in plan, elevation and section, and on a larger scale a diagram of stresses and the necessary details.

DEPARTMENT OF MECHANICAL ENGINEERING.

COTTON MANUFACTURE AND THE RING FRAME. ABSTRACT BY THE AUTHOR, F. H. SILSBEE.

In this thesis I have endeavored to present, more or less fully, the following points.

1. A general description of the growth of cotton cultivation, since the improved facilities for manufacturing it, and the structure of the cotton fibre.

2. The history of the introduction and progress of the cotton manufacture, and the most important inventions of cotton machinery, from the first introduction of this industry into England in 1760, to its introduction into this country in 1787, when the first cotton factory was built at Beverly, Mass.

3. A general account of the process of the manufacture of cotton cloth from the raw material, together with a slight description of the various machines employed and the object of their use.

4. The special spinning machine known as the Ring Frame, which is now so universally adopted in this country, especially for spinning the warp. This subject I have entered into the most fully, giving

(a) A brief history of the invention of the Ring Frame, which is due to John Thorp, of Providence.

(b) A general description of the frame, illustrated by a drawing; and also a detail description of the mechanism by which the traverse motion is obtained.

(c) An account of some of the most important styles of spindles and rings.

(d) Tables showing the power required to drive the various spindles, and also the power required to drive the frames under different conditions of banding.

(e) A table showing the strength of the Throstle, Ring, and Mule yarns.

(f) A summation of the merits and defects in the Ring Frame, as compared with the other spinning machines.

(g) An examination of the relative motion of the traveller and spindle, which shows that the traveller loses one revolution each time the yarn is wrapped once around the bobbin.

(h) A consideration of the matter of real and apparent twist, and the rules ordinarily adopted for calculating the same.

(i) A calculation of the irregularity in the twist, which arises necessarily from the manner in which the yarn is unwound from the bobbin, which shows that this irregularity is very slight.

(j) An examination of the effect on the evenness of the yarn which the traverse motion causes; from which it appears that this motion produces no error in the twist.

(k) A calculation of the comparative work of friction of the ordinary or heavy spindle, weighing 11 ounces, and the Sawyer Spindle weighing 3½ ounces; from which it is shown that about 36 per cent. of the difference of power required to drive the two frames is due to the friction arising from the weight of the spindle and empty bobbin, and diameter of step, the rest of the difference being probably used up in overcoming the friction caused by the tightness of the bands.

(l) A calculation of the speed of the traveller through

space, which is found to be at the rate of 30 miles per hour, when the spindles make 6,000 revolutions per minute.

THE CORLISS STEAM ENGINE. ABSTRACT BY THE AUTHOR, FRANK H. POND.

The earlier steam engines may be considered as steam-pumps, and that of Newcomen the connecting link between the steam-pump and the modern engine. Newcomen's engines, improved in various ways by Brindley, Smeaton, and other engineers, continued in use during the greater part of the last century; but it was in effect the same until the days of Watt, the result of whose labors has been a harvest of wealth, prosperity, and ingenuity, without a parallel in the history of the world.

I considered my subject in three parts.

Part First. The Efficiency of Heat Engines in general.

Part Second. The Efficiency of the fluid in Steam Engines. I deduced the formulæ for finding the area of the Indicator diagram, assuming a theoretical diagram as being the most simple from which to deduce them. This theoretical diagram is constructed upon four suppositions.

1. That the steam, when it enters the cylinder, presses upon the piston with the elasticity existing in the boiler.

2. That this pressure continues uniform, as long as the steam valve remains open.

3. That after the steam valve is closed, the pressure diminishes inversely as the volume of steam increases by expanding, according to Mariotte's law.

4. That the exhaust port is opened at the instant the piston reaches the end of its stroke, and remains open during the entire return stroke. Now this very seldom happens, as is shown by experience. The causes which affect the power of the engine, as well as the figure of the diagram, are wire-drawing at cut-off, clearance, compression, or cushioning, release, conduction of heat, and liquid water in the cylinder.

I then considered the effect of back pressure; the thermodynamic functions, and adiabatic curve, for mixed water and steam; the approximate formula for adiabatic curve; the liquefaction of steam working expansively; and the efficiency of steam in a non-conducting cylinder, of which the Corliss engine is a good example.

Part Third. The efficiency of steam in the Corliss engine. As Watt, in the last century, found the steam engine an imperfect and wasteful arrangement for utilizing only a small portion of the energy of the steam supplied to it, and by the invention of a separate condenser, and by his method of making the engine double acting, made it really a steam engine, so in this country the credit belongs to George H. Corliss, of Providence, R. I., for improvements by which, in the engine known under his name, simplicity of construction, together with perfection in economy of working have been secured. The improvements which Mr. Corliss has made in the mechanism of the steam engine, have been recognized by the American Academy of Arts and Sciences, and publicly acknowledged by this body in presenting him with the Rumford Medals, in January, 1870. I will give only one short extract from the address made upon the occasion by Dr. Asa Gray, President of the Academy, although in my thesis I have quoted at some length from it, as he gave a very fine description of the engine. After noticing the economy of fuel which the Corliss engine makes possible, compared with the older forms, Dr. Gray continues, "It is a great thing to say, but I may not withhold the statement, that, in the opinion of those who have officially investigated the matter, no one invention since Watts' time, has so enhanced the efficiency of the steam engine, as this for which the Rumford Medals are now presented."

The Corliss engine, from which I have taken my data in the following calculations, is a one hundred horse-power engine, built by the Corliss Steam Engine Co., Providence, R. I. The engine has been running about six months, in the largest printing house in the country, Messrs. Rand, Avery &

Co., 117 Franklin Street, Boston, Mass. The diameter of the cylinder is 18 inches, length of stroke 4 feet; when running with 60 lbs. of steam by the gauge, the engine makes 55 revolutions per minute. I took indicator diagrams from the engine April 18, 19, and 20 (1874). Diagrams will be found with the thesis, which were taken on each day, showing the manner in which we found the valves set, and as we left them. On April 19, we ran only the shafting, and found it took 20,082 horse-power. They were also running very light on April 20, the diagrams show 51.535 horse-power, or about half the capacity of the engine.

The following table shows the different ratios of expansion:

Rankine's correct (?) method	$r = 3.901$
" approximate "	$r = 4.369$
From indicator card, calculating the clearance .	$r = 5.61$
" " " measuring clearance with water	$r = 5.17$

Energy per cubic foot of steam admitted, 9014.986 foot-pounds.

Mean effective pressure, or energy per cubic foot swept through by piston, 12 lbs. per square inch, when $r = 5.17$.

Heat expended per cubic foot of steam admitted, 130305.5 foot-pounds.

Heat expended per cubic foot swept through by piston, or pressure equivalent to heat expended, 175 lbs. per square inch.

Net feed water per cubic foot swept through by piston, .028 cubic feet.

Efficiency of the steam nearly 7 per cent. (.069)

THE SWAIN TURBINE. ABSTRACT BY THE AUTHOR, GEORGE H. BARRUS.

The Swain Turbine is what is known as a combined parallel and inward flow turbine. As the name of the class to which it belongs implies, it combines the forms given to parts of two dif-

ferent turbines, into a single one of the same size. The openings into the wheel embrace the upper part of its periphery, the remaining part of the depth being closed by a band. The orifices of discharge lie at the bottom and the inside, extending from the under side of the crown to the lower edge of the band. The direction of motion of the particles of water in passing through the buckets varies from a horizontal to a vertical direction, depending upon their positions on entering. The vertical components of these motions act in the same manner as the water in a parallel flow turbine, while the horizontal components act like the water in a real inward flow turbine. The condition of maximum flow through the wheel is satisfied by making the area of the gate openings equal to that of the orifices of discharge.

This subject is considered under five heads. The "Description of the Swain Wheel" consists mainly of the explanation of a sectional elevation of the wheel as it sets in quarter-turn.

Under "Construction" reference is made to some of the rules used in proportioning the principal parts, the method of laying out the bucket curves, and the process of casting the wheel. A few improvements are explained which were devised by Mr. A. K. Mansfield.

The third division is headed "Theory," and contains an explanation of the action of the water as it passes through the wheel, showing the deviation which it undergoes in encountering the curved bucket. The wheel is first considered as an actual inward flow turbine, and the formulæ derived are afterward changed by introducing the mean horizontal component, before referred to, making them applicable to the real case. In the next place, the equivalent parallel flow turbine is investigated with results of a similar character. In both, the principal object in view is to obtain the velocity of the water leaving the wheel, from which the efficiency, neglecting prejudicial resistance, is easily deduced. The formulæ serve also to show the proper values of the angles, guides, and bucket curves within certain limits.

Under "Method of Testing" a general description is given of the process of testing a turbine by the use of the dynamometer; and the method of computing the efficiency from the results of such a test. The last topic embraces a comparison of the Swain wheel with other turbines in use at the present time. With economy as the basis of comparison, two points are made which should be borne in mind in an examination for relative merit—efficiency and power. It is desirable that a turbine should possess both these qualities in as large a degree as possible.

The different methods of regulating the supply of water to the wheel are noticed and their effects upon the efficiency at part gate compared. A short table containing the efficiencies and powers of a few prominent turbines shows how these remarks apply.

DYNAMOMETERS. ABSTRACT BY THE AUTHOR, WILLIS H. MYRICK.

Whatever causes, or tends to cause, increased or decreased motion in a body is a force. The continuous action of a force through space is work, the amount of which may be expressed by the product of the force, and the space passed over by that force. Power is the rate of work, or the work performed in a unit of time.

The various uses of the dynamometer are to determine the force exerted, the work performed, or the power expended, wherever motion takes place or tends to take place. Of those kinds which have for their object the determination of force alone, the most prominent were invented by Graham, Desaguliers, Leroy and Renier. Graham's instrument as well as Desagulier's were modifications of the common steelyard, while Leroy's was similar to the spring balance. Renier's consisted of an elliptical spring very much like a carriage spring having a scale and pointer so attached that it showed the force applied.

As most of the dynamometers for measuring work can be used for measuring power, and *vice versa*, the different varieties

will be mentioned together under the heads of Traction, Transmission, or Absorption Dynamometers. Of the Traction form, Morin's is the only one which needs describing. It consists of two parallel rectangular springs, connected at their extremities, whose deflection taken with the distance passed over by the carriage determines the work.

A Transmission Dynamometer consists essentially of two pulleys, or shafts, one driving and the other driven, these being connected by springs, levers, or gears, in such a manner that they use up an amount of force equal to that which is necessary, at any instant, to produce the required motion, in the machine to be tested. The compression of the springs, or the amount of weight raised with the space and time, give the means of determining the power, or work. The connection between the driving and driven pulleys or shafts, varies in the different machines. In Morin's rotary dynamometer, it consists of a flexible rectangular bar, one end of which is fixed to the shaft the other to the driving pulley. A pencil is made to record the force on a moving strip of paper.

Eive's is a dynamometer with two radial springs projecting from the hub of one of the pulleys, whose extremities press upon two pins on the circumference of the other. The motion of one pulley relatively to the other, pushes the end of a rod over a cam. The motion of the rod indicates the force. Mr. Taurines has a dynamometer where the ends of two arms on the shafts are connected by springs, whose flexure determines the force. S. P. Ruggles of this city has one consisting of a pulley connected to the shaft by means of a spiral spring which encircles it. A screw and thread within the hub moves a rod which connects with the recording apparatus. Mr. Hirn obtains the work done by means of the torsion of the shaft itself. Brown's connexion consists of three spur gears in line. The middle one is small, and is attached to the short arm of a steelyard. Bachelder's is of the same principle, except that the combination, commonly called compound gears, are used instead of the spurs. Mr. Neers connects the driving with the

driven shaft by means of two discs, one fixed on the inner end of each shaft. To that disc which is connected to the driven shaft, are attached two springs which oppose the motion of two chains that pass over two small wheels, on the circumference of that disc, and connect with the other disc. The motion of this second disc pulls the chains over the small wheels, while the springs opposing their motion cause the first disc to turn with it.

Emerson's transmission dynamometer consists of a combination of compound levers, connecting the driving pulley to the shaft of the driven. The force is measured by a weighted pendulum.

While examining the defects which are so detrimental to transmission dynamometers as a class, the springs which most of them use form one of the most serious, as well as one of the most common. These springs are not only affected by temperature and by age, but from the effects of centrifugal force are pulled and twisted as they revolve around the rotating shaft, thereby causing false indications. Unbalanced parts rotating around a shaft are also acted upon by centrifugal force.

Upon examining Brown's and Batchelder's machines, we find that these defects are overcome, but in their stead, we find a force in motion which is carried through revolving gears, at high speeds, causing imperfect indications.

In the dynamometers about to be described, every precaution has been taken to overcome these objections, and to obtain what seems to be a dynamometer with but few, if any defects, except those of friction, which it is impossible to get rid of entirely. The following is the description of a machine which has been designed. Two short hollow shafts are situated in line with their inner ends somewhat separated. Each carries a pulley which may serve as a driving or driven pulley, together with a bevel gear placed at its inner end. Between these bevel gears and opposite each other are situated two smaller bevel gears, forming a set of compound gears. Each small gear connects by means of a short hollow shaft with a spur gear, the spurs being near the centre of the machine, their planes paral-

lel to each other, and to those of the small bevels. Each spur gear works in a rack, one rack being on the top of one spur gear, while the other rack is at the bottom of its spur. Both racks are connected to a rod which runs lengthwise of the machine, and through the hollow shafts first spoken of, appearing at the outer end of one. The rod here terminates in a step, the step pressing against a small steel block, which by means of a rack on its under side connects with a spur gear, to which is fastened a weighted pendulum.

If for an instant the driving pulley remains still while the driven pulley revolves, the small bevel gears will turn, consequently the spur gears, which will force the rod against the block, causing the pendulum to be raised. The pendulum reacts through the different parts, as the springs react in the other machines. Calculations have been made of the sizes of the various parts, but space will not permit their being inserted here.

Of the Absorption Dynamometers, the Prony Brake consists of several pieces of wood, connected by chains, which surround a shaft or pulley, they being held against the shaft or pulley by these chains which are connected to the short arm of a steelyard, the long arm being weighted until the shaft runs uniformly.

Mr. Emerson has made an improvement on this, by encircling the pulley with a hollow iron or brass band instead of the wooden blocks, water being forced through the band to keep it cool.

DEPARTMENT OF ARCHITECTURE.

DESIGN FOR A COUNTRY RAILROAD STATION. ABSTRACT BY THE AUTHOR, W. B. DOWSE.

This design was a solution of the problem given out in the Architectural department for a railroad depot, situated in a country town and which was to be built over the track. In its construction, stone or brick, iron and wood were to be used and

it was to be so arranged that persons could pass from their carriage to the train, under cover. To meet these requirements a bridge was designed, formed of circular stone ribs, at regular distances from each other and having a solid backing up to forty-five degrees, the stone ribs being bound together by brick-work. Stone and brick were also used in the outside walls of the building itself, to a height of about four feet, and in the signal tower, to the height of the roof of the main building. Iron was employed in the corridors and stairways, forming the covered passage to the trains below. The rest of the building was to be of wood. Through the backing of the ribs of the arch runs an arched corridor, giving additional breadth of platform.

Simultaneous with the designing, approximate calculations of the strength and stability of the parts were made, but as the building was not to be large, and consequently the strains upon its parts small, as also those upon the bridge, it was found that to have any architectural beauty many of the dimensions would have to be larger than they were required to be for strength. After the design was finished the calculations were made again, showing the *necessary* size of the component parts.

The frame of the roof consists of four intersecting trapezoidal trusses. The strains on them are due to the weight of roof. They must also be able to support the roof when loaded with snow. It was found that to resist the compression in the upper beam of the trusses it must have a cross section of 23 square inches. The necessary dimensions of the other parts were also calculated. The strength of the cast iron columns supporting the iron corridor, to sustain the weight of roof when loaded with snow, being the greatest strain it would be subjected to, was calculated and the cross section necessary was only .133 square inch, too small to be cast, as the columns were hollow and served as gutters, the real cross section being 18.06 square inches. The stability of the signal tower to resist the wind was found to be ample, as the necessary cross-section of each of the four main timbers of the frame, in order to resist compres-

sion or extension, according to which side the wind acted on—was only 3.08 square inches, but being used for ornamental purposes also, they were much larger. The necessary cross-section of the braces was also found. The track ran through a cut making it necessary to construct walls, in this case surcharged, battering-faced retaining walls, on each side. The necessary thickness of the base of the wall was found to be 3.86 feet. Its stability of friction was also found and the necessary depth of foundation, disregarding frost, was 2.47 feet. Calculations were also made on the strength of the brickwork of the arch and also of the stone ribs.

DEPARTMENT OF CHEMISTRY.

A FEW INSTANCES, SHOWING THE POSSIBILITY OF APPLYING THE MICROSCOPE TO INORGANIC QUALITATIVE ANALYSIS.

ABSTRACT BY THE AUTHOR, FRANK W. VERY.

I. Introduction. *a.* Disadvantages of the method; 1. High magnifying powers are required; 2. It is not so delicate as the ordinary one. *b.* Advantages of the method; 1. A small amount of substance suffices for an analysis; 2. It is more rapid than the ordinary one; 3. One test often detects two or more elements.

II. General directions for performing the microchemical analysis, together with some remarks as to the kind of tests which should be chosen in forming a system. (*a*) Apparatus. (*b*) Tests, embracing 1. Precipitation by chemical reaction. The largest crystals are formed from moderately dilute solutions; 2. Precipitation by a less solvent liquid. The production of crystals by the agitation of supersaturated solutions is often useful; 3. Crystallization by evaporation. The crystals produced in this way vary more than the precipitated ones; 4. Electrical deposition of metals.

III. Special cases. Scheme for detecting lead, bismuth, copper and cadmium in presence of each other. Embracing, *a.* Precipitation as carbonates by sodic carbonates. *b.* Solution

in nitric acid; 1. Precipitation of basic nitrate of bismuth by water; 2. Precipitation of plumbic nitrate by alcohol. *c.* Solution in chlorhydric acid; 1. Precipitation of plumbic chloride from the hot solution; 2. Evaporation of the chlorides of copper, cadmium and bismuth; 3. Evaporation with potassic chloride for cadmium. *d.* Solution in acetic acid; 1. Precipitation or evaporation of cupric acetate.

Scheme for distinguishing barium, strontium and calcium in presence of each other. Embracing, *a.* Precipitation as carbonates. The ordinary method. *b.* Solution in chlorhydric acid; 1. Evaporation of the chlorides of barium, strontium and calcium; 2. Precipitation of basic chloride by alcohol, also occasional precipitation of chloride of strontium; 3. Precipitation of the oxalates of barium, strontium and calcium, by ammonic oxalate and also by oxalic acid.

DEPARTMENT OF MINING ENGINEERING.

EXPERIMENTS ON WINNAMUCK SILVER LEAD ORES, FROM BINGHAM CANON, UTAH. BY B. E. BREWSTER.

REPORT ON THE DRESSING AND METALLURGICAL TREATMENT OF AN ARGENTIFEROUS LEAD ORE, FROM GEORGETOWN, COLORADO. BY F. H. JACKSON.

For full summaries of these theses, see "Studies in the Mining and Metallurgical Laboratories," on page 38.

DEPARTMENT OF SCIENCE AND LITERATURE.

FRANCE. BY ROBT. C. WARE. ABSTRACT.

Exceptional position of France in European history; an examination attempted of her present resources and condition, and of her past history, in order to forecast her probable future; difficulty of the subject; list of authorities; situation of France; frontier and coast surface; water-shed and river system; geology; volcanic formations; extent of tertiary and alluvial deposits; poverty in mineral wealth; climate; rainfall; agriculture;

forests; statistical tables from M. Block; population and its movements; slowness of increase.

Periods of history; barbaric, feudal, monarchic, revolutionary; extended sketch of each period; France since the fall of Napoleon III.; administration of Thiers; payment of indemnity; nature of the present provisional republic; debt; revenue; cost of the war; paper currency; exports and imports; division of land; loss of power by the R. C. church; education; immense recuperative power and favorable prospects as compared with Spain.

RUSSIA. BY S. H. WILDER. ABSTRACT.

Early condition of Russia; growing importance since the Crimean war; extent and general physical characteristics of the empire; northern Russia; central and southern Russia; surface and climate; water communication; detailed account of the geology of Russia; agricultural productions; forests; cattle, horses, sheep, etc.; mineral products; statistics of manufactures; railways and internal communication; foreign commerce; ethnology of the Russian empire; character and divisions of the Sclavonic race; the Finns and Lapps; early history; career of Peter the Great; reign of Catherine II.; Nicholas and the Crimean war; reforms under Alexander; emancipation of the serfs; Russian communism; the Russian church; the army; literature; list of thirty-six authorities consulted or read.

REPORT OF THE DEPARTMENT OF MECHANICAL ENGINEERING.

President Runkle: —

DEAR SIR: — Since my report to you, made one year ago, quite important changes have been made in the course of instruction in this department. Two principal causes have led to these changes. They are,

1. The entire reorganization of the courses of instruction carried on in the Institute.

2. The existence of the long desired Mechanical Engineering Laboratory.

The nature of the reorganization of the courses of instruction was made very clear in the catalogue published one year ago. The scheme has worked admirably in my department, and while the duties of instruction in the strictly professional work of the course have been much increased, it has been possible to give the students a much more practical, thorough, and extended course of professional study.

The nature and uses of our Laboratory will be explained somewhat in detail in the latter part of my report.

We have now five sub-courses of professional instruction: — Mathematical, practical, graphical, excursional, and experimental. The number of text books and professional papers made use of in the course of instruction has been much increased. The same subject is, when practicable, under consideration in each of the five sub-courses at the same time. Such subjects

are selected for the consideration of the students as seem most important to the head of the department.

The text books to be used, the excursions to be made, the proper drawing and laboratory exercises are then arranged for; the object in view always being to give the students the most correct and practically valuable view of the subject that the time will allow.

My last year's report gives an idea of the work done in each sub-course, except the experimental. But it also suggests an experimental laboratory.

During the early part of 1874, all schemes for fitting up the laboratory fell through; but a little later, Mr. Geo. B. Dixwell called to consult me concerning certain questions relating to the nature and behavior of steam in some of its applications. I found that he had carefully examined a very large number of the best recorded experiments which bore upon the questions concerning which he wished to be enlightened. As some of his questions could be most satisfactorily answered by appealing to direct experiment, I advised him to go to some engine builder and undertake in connection with him such a series of experiments as would give him the desired information.

I further expressed my regret that our laboratory was not in active operation, as in that case we should be able to answer his questions at the Institute. He corresponded with engine builders upon the subject, but after deliberation decided to have the experiments conducted at the Institute. He saw that this decision would increase the expenditure that he would necessarily be at for the purpose of gaining his information. He also saw that in case the experiments failed to result as he anticipated, his expenditure would not be wasted, for he would have aided in establishing a Mechanical Engineering Laboratory, whose value, if properly used in a course of instruction, could hardly be over-estimated. It would make students familiar with the properties of steam on such a scale that the results obtained would be of *direct* value in their future practice, and of *direct* interest to all users of steam power. It would give them facili-

ties for becoming skilful in the manipulation of instruments used by engineers in testing steam boilers, engines, and kindred apparatus. They could be made familiar with, and thus taught to avoid the *legerdemain* of these instruments, by means of which some men frauduently, and many men ignorantly or carelessly, deceive the public or themselves.

To meet the generous contributions of Mr. Dixwell, I have, with your approval, made suitable expenditures. Two horizontal, wrought iron, multi-tubular boilers, which were formerly used for heating purposes merely, have also been connected with our apparatus.

I would now respectfully invite your attention to detailed descriptions of some of the more important parts of our apparatus, saying, once for all, that most of these descriptions were written by Mechanical Engineering students as regular Institute exercises. They formed parts of reports of experiments conducted by the students. I have taken the liberty of revising or of making such abstracts as seemed best, from their reports, and of then making them a part of this paper.

The Hot-water Collector described in the "Spectrum," a paper published last year by the students, is a plain, horizontal cylinder, its inside length being 13 feet 10 inches, and its inside diameter being 3 feet. The cylindrical part of the shell is of wrought iron, $\frac{3}{8}$ of an inch thick. The ends of the shell are flat cast-iron plates, 1 inch thick. The capacity of the tank is 97.78 cubic feet. It receives the hot water which condenses in the steam heating apparatus, and retains it until it is needed again in the boilers. The hot water is carried from this collector to a *Blake Pump*, through a 2 inch pipe, connected with which is a small cold water pipe for cooling the water, if necessary, before it reaches the pump. From the pump a $1\frac{1}{2}$ inch pipe passes along the front of the boilers. From this pipe a 1 inch pipe leads into each boiler. A cold water pipe is also connected with the $1\frac{1}{2}$ inch pipe. Its water will run into either boiler under 40 pounds pressure without the aid of the pump.

A Giffard's Injector, made by Wm. Sellers & Co., of Philadelphia, also forms a part of our boiler-feeding apparatus.

The Steam Producing Boilers, also described in the "Spectrum," are virtually alike, and the description of one is virtually that of the other. Each is 12 feet long, 4 feet diameter, and has fifty tubes, each of which is 3 inches outside and 2¼ inches inside diameter. About one half of the cylindrical part of the shell, both tube sheets and the inside surfaces of the tubes come in contact with the heated gases. The total area of heating surface per boiler is 530.35 square feet. The total boiler room is 121.34 cubic feet.

The following table shows the proportions of steam, water, and boiler room under certain circumstances:—

Height of Water.	*Cubic Feet of*		*Percentage of boiler room occupied by*	
	Steam.	*Water.*	*Steam.*	*Water.*
Lower Gauge Cock . .	65.42	55.92	53.9	46.1
Middle " " . .	49.72	71.62	41.0	59.0
Upper " " . .	36.59	84.75	30.2	69.8

There are suitable safety valve gauges, etc., on each boiler. Both boilers are provided with Etna grates; the grate area of each is 16 square feet. Two inspectors of the Hartford Steam Boiler Inspection and Insurance Company have certified that they have carefully inspected these boilers, that they find them in good condition in every respect, and that they are well adapted to bear with safety a pressure of 80 pounds to the square inch. They were built by Allen and Endicott, of Cambridgeport, in 1866. Two wrought iron chimneys carry away the waste gases from the two boilers; their capacity to carry off smoke is about one-half what is needed, and the result is at once an insufficient supply of steam and a wasteful consumption of coal. I would respectfully recommend that a suitable chimney, or a mechanical blast, be provided in order to remedy the defect.

The Small Boiler, described by Thomas D. Plimpton, is of the upright, wrought iron, tubular class, 7 feet long, and 8 feet

in diameter; the distance between the tube sheets is 5 feet and there are 50 two-inch tubes. The tubes, and also 12 stays each $\frac{3}{4}$ of an inch in diameter, connect the tube sheets with each other. The water space below the lower tube sheet is an annular ring, measuring 2 inches in a radial direction. This space is more strongly stayed than is usual in boilers of this kind. The boiler is set in brick work with a space left around its upper part, extending downward not quite so low as the lower tube sheet. The hot gases pass through this space, after leaving the tubes on the way to the chimney. The furnace and combustion chamber are detached from the boiler, and the hot gases can be directed through the boiler to the chimney, in which case, they give up their heat to the contents of the boiler, or the whole or any desired part of these gases can, at any time, be made to pass to the chimney by a flue which avoids the boiler entirely. This boiler always superheats the steam more or less, more in proportion as the water level is lower. It is provided with two sets of gauge-cocks, one set near the top and the other set near the bottom of the boiler. Glass gauges run from near the top to near the bottom.

Instead of using this boiler as a steam producer, it may be used as a superheater, or again, as a steam drum or "mechanical separator" merely. When used as a superheater or steam drum, steam is introduced from the producing boilers by a pipe 2″ diameter which enters the small boiler at the top and passes down into it about $3\frac{1}{2}$ feet. A deflecting plate prevents the escaping steam from impinging upon the surface of the water in the superheater or drum, should any water be there. The exit pipe is at the top and on the opposite side from that at which the admission pipe enters. This boiler was tested by an hydrostatic pressure of 250 lbs. per sq. inch. Two inspectors have pronounced it safe with a steam pressure of 150 lbs. per sq. inch. This boiler was built in the best manner by Thomas Cunningham, of Charlestown.

The Cast Iron Superheater, described by Thomas D. Plimpton, is a cast iron box, 4 feet long, 2 feet wide, and 4 inches

thick. It has partitions extending crosswise alternately from one side nearly to the opposite, causing the steam to take a zig-zag course as it passes through, and bringing the moving steam in contact with all its parts. These partitions also serve for stays and practically increase the area of heating surface.

It lies flat over its furnace; the hot gases passing over the back end, return over the top and then pass into a flue. This flue conducts the waste gases, still quite hot, through the tubes of the small boiler, or directly into the chimney at pleasure. This Superheater was presented by Prof. John M. Ordway, of the Chemical Department.

The Steam Engine is a Harris-Corliss, and was built for us by Wm. A. Harris, of Providence, R. I., who says that it was built in his best manner.

The cylinder of the engine is about 8″ by 24″, the clearance about .036 of the piston displacement. It does not differ in its general style from the usual Corliss Engine pattern. It is regulated to make about 64 revolutions per minute, and when cutting off at half stroke, produces about 20 horse power, with 70 lbs. initial pressure in the cylinder. The governor furnished with the engine is of the ordinary "common pendulum" variety, and like all Corliss Engine governors, regulates the admission of steam by varying the point of cut-off. The ordinary throttle valve has been removed from the engine, and a Huntoon Governor put in its place. This governor is, as is well known, a throttle valve governor. It was presented to the Institute by E. P. Boardman & Co., of Lawrence, manufacturers of the governor, in answer to our request for their lowest price. We can at pleasure control the engine with either governor. When one governor is in use, the other is made entirely inoperative. A Peet Valve in the steam pipe is used as a throttle valve.

The Principal Parts of the Calorimeter described by Geo. H. Barrus, a graduate of the Mechanical Engineering Department, and my assistant in the laboratory, are *a Brass Coil or Surface Condenser*, which does not leak; *a Small Tank* beneath, in which to collect the water which condenses in or

passes through the calorimeter; *Scales*, for weighing; *Thermometers*, for ascertaining temperatures; *a large, closed, rectangular wooden Tank*, containing the brass coil, the water which absorbs the heat that passes through the walls of the coil, and *the pump* which circulates the water; and *an Expansion Tank.*

The exhaust pipe of the engine passes through the wall of the large tank near one end and about two and one-half feet above the floor of the tank, where it is permanently attached to a nearly horizontal tube three inches in diameter and four feet long which forms a part of the coil or condenser. Another 3-inch tube lies parallel to this, near the floor at the other end of the tank. These 3-inch tubes are joined by a row of 20 Z-shaped brass tubes, one inch in diameter and 21 feet long. The Z-shaped tubes run the length of the tank, three times, falling about ten inches in each length. All the joints of the Z-shaped tubes and of the nearly horizontal tubes which they connect, are so designed that no cavities are left to collect water which condenses. When it is desired to measure the quantity of heat which is contained in a given mass of steam or water, that steam or water after traversing the exhaust pipe enters this nearly horizontal tube. All of the tubes slant sufficiently to allow any water which may arrive at or condense in any part of the coil to fall readily into a five-eighths of an inch drip pipe, which leads from one end of the lower 3-inch pipe. The drip pipe passes through the bottom of the large tank into a small tank beneath. Between the two tanks the drip pipe contains two check valves and a Chapman valve. The former prevent the water from being pressed back into the coil by the atmospheric pressure when the steam ceases to enter it. Air gains admission to the coil through a vacuum valve in the exhaust pipe near the tank. Whenever water enough has run into the small tank, the Chapman valve can be closed at any time, preventing all water from passing out of the coil. The water in the small tank can be carefully weighed, drawn off, and the weight of the empty tank taken in a short time. The

efficiency of the condenser is not diminished enough through the backing up of the water confined in the coil to affect very much the back pressure of the engine. This coil was carefully tested for leakage by letting on the full head of Cochituate water, the pressure of which was in excess of 40 pounds per square inch. At first there was leakage through minute blow-holes in the cast brass connections, and at some of the junctures of the tubes; but these defects were remedied by the application of soft solder. The tubes themselves are of seamless drawn brass, and, except in one or two points, exhibited no tendency to leak.

The Small Tank is made of 2-inch plank, four and one-fourth feet long, thirteen inches deep and thirteen inches wide. It is provided with a floating cover. A sheet rubber diaphragm extends from the outside edges of this cover to the inside edges of the top of the tank. The cover and diaphragm prevent the formation of vapor in the small tank. Without them, the water in the tank would lose both weight and temperature through surface evaporation. The outlet of this tank is a 3-inch pipe opened and closed by a Chapman valve. Only fifty seconds are required for emptying this tank. A Huddleston thermometer indicates at any time the temperature of the water contained in the tank. The weight of that water is indicated from second to second by the four hundred pounds Fairbanks' Scales upon which it rests. The ringing of an electric bell indicates the rising of the scale beam. Horizontal pieces of rubber hose of sufficient length connect the tank with all pipes leading to or from it. As the level of the platform of the scales changes but slightly during the operation of weighing, the rubber hose is but slightly bent and the sensitiveness of the scales is not much diminished. The rubber hose also serves to intercept the conduction of heat to or from the tank. Air communication with the inside of the tank can be made when desired, by a small valve provided for the purpose.

The Large Tank is built of 2-inch plank, strongly bolted together. Its inside dimensions are, length seven feet two

inches, width four feet two inches, depth four feet two inches. It is connected with the Cochituate hydrant by a 2-inch pipe which is opened and closed by a Peet valve. A Huddleston thermometer for determining the initial temperature of the Cochituate water used in the calorimeter is screwed into this pipe. It is about twelve inches long, and is graduated from about thirty degrees Fahrenheit to about one hundred and twenty degrees Fahrenheit. The bulb of the thermometer is surrounded by the water in the pipe and is subjected to the pressure of the water. The thermometer is quite near the large tank. The effect of the pressure on the surface of the bulb is not worth considering.

The outlet of the tank is a 3-inch pipe which leads from the bottom of the tank to the waste pipe. This is opened and closed by a Chapman valve. The tank fills in thirty-three minutes and empties in fifteen minutes. The faucets at one end of the large tank, one at the top and one at the bottom, allow water to be drawn from the tank, and two Huddleston thermometers, similar to those in the Cochituate pipe, except that the graduation extends to two hundred and twelve degrees Fahrenheit, one at the top and one at the bottom of the tank, show the temperature of the tank water.

The large tank rests upon a pair of five ton Fairbanks' Scales. All pipes leading to or from the tank are connected by horizontal pieces of rubber hose so long that their direction does not change much during the operation of weighing. The scales are sufficiently delicate to indicate a change of one pound in the weight resting on the platform. The rubber connections are of service in checking very much the transfer of heat to or from the tank. That one which is in the exhaust pipe has a stout spiral spring of about the same outside diameter as the inside diameter of the connection within it and running nearly its whole length, but not touching the pipe at either end. The pitch of the spiral is about three and one-fourth of an inch, and it serves to prevent the rubber from collapsing, when the steam is shut off before the atmospheric pres-

sure opens the vacuum valve. A safety valve attached to the exhaust pipe would blow off if the pressure in the pipe should ever reach ten pounds per square inch. No pressure, then, at all approximating to the bursting pressure of the rubber hose can ever come upon it.

The temperature of the water in the top of the tank would be much in excess of that of the water at the bottom, were it not for the *Circulating Pump*. This draws the cold water from the bottom and discharges it at the top, thoroughly mixing it. The induction pipe, about three-fourths of an inch by four feet, in cross section, is situated between one end of the coil and the same end of the tank. It begins near the bottom of the tank and extends upward as far as the top of the coil where it is terminated by a clap valve, about four feet long, opening upward. Passing through the valve the water enters a chamber reaching in height to the top of the tank, and about one foot by four feet in the plan. Leading out of this chamber near the middle of its length, is a rectangular trough, about four feet long and nine inches square, in cross section, in which the pump piston reciprocates, and through which the water passes out of the pump.

The Piston Head is a block of wood surrounded by a flanging piece of rubber which fills the trough during the forward stroke but collapses during the backward stroke, thus serving the purpose of a valve. It is worked by a rod which projects through a stuffing-box in the side of the tank. When eight hundred pounds weight of steam per hour is condensed in the coil, it is easy to keep the temperature of the water at the bottom of the tank within one degree Fahrenheit, or less, of what it is at the top, by means of the circulating pump.

The Expansion Tank is two feet square in the plan, and two and one-half feet deep. It gives the water an opportunity to expand as it receives heat through the walls of the coil. Without it, the expansive force of the heating water would readily burst the closed tank. With it, the hydrostatic pressure can never reach two and one-half pounds per square inch. A

2-inch connecting pipe passes upward through the cover of the large tank, and through the bottom of the expansion tank. A floating cover and rubber diaphragm similar to those of the small tank serve here a similar purpose. A valve in the side of the expansion tank allows communication with the air while the large tank is emptying or filling. The large tank is known to be full when the cover of the expansion tank is seen to float.

The Standard Test Gauge attached to the small boiler, described by Thomas Hibbard.

This Bourdon Gauge was manufactured by the American Steam Gauge Company expressly for the Institute, and is of the largest size. We understand that they have put their best work into it, and took the greatest care in graduating it, in order to make it as nearly as possible a Standard Test Gauge. It is graduated to one hundred and forty pounds subdivided to half pounds. The Company's Mercurial Column was used in graduating the dial. Both the gauge and the column were subjected at the same time to hydrostatic pressure, until the column indicated the desired pressure, say one pound per square inch. The proper graduation marks were obtained in a similar manner.

The gauge is attached to the exit pipe of the small boiler by a U-tube, five feet deep, which is filled with water to its highest level. By this means the tube of the gauge is entirely cut off from the *heat* of the steam, while the water readily transmits the pressure on its exposed surface to the air confined in the gauge. The advantage of this is obvious, for it is a well known fact that a gauge exposed to heat reads very differently at different temperatures. In fact, a Bourdon Gauge, under some circumstances, makes a very good pyrometer.

The Pressure Gauge on the Eastern Producing Boiler was made by the same process and by the same makers as the Standard Test Gauge. It is not quite as large as the test guage, but it was made with equal care.

The Thermometers used in determining the temperature of the steam, described by James H. Head, are two in number

and were made for us by Mr. Huddleston of this city. They are substantially alike. Each is about twenty inches long, and gives readings at intervals of two degrees from two hundred degrees Fahrenheit, to a little less than six hundred degrees Fahrenheit. They were graduated at atmospheric pressure by comparison with a standard thermometer and by calibration, thus giving a great degree of accuracy in their divisions. During some experiments the bulbs are immersed directly in the steam whose temperature is to be measured. The metallic case of one of the thermometers is screwed into the steam pipe about ten inches from the pipe leading to the gauge, so causing the bulb to be in the pipe and entirely surrounded by steam. The pressure of the steam on the bulb causes an error of excess in the readings, very slight at low pressures but increasing as the temperature and pressure increase. During other experiments a cup containing mercury is screwed into the opening of the steam pipe referred to. The thermometric bulb being immersed in the mercury acquires its temperature, which under certain circumstances will not differ materially from that of the steam.

Two of Bulkley's Pyrometers have been provided for ascertaining the temperature of the superheated steam. One of these is inserted in the steam pipe, between the place where the superheated steam passes into this pipe and the engine.

Two Richards' Indicators have been made for the Institute by the American Steam Gauge Company. Their springs were coiled from wire which was at first a little too stout. They were then reduced as much as seemed necessary, being tested from time to time by the process now to be described.

An indicator with its spring, pencil and card all in position, was reversed, so that its piston rod pointed vertically downward. A scale pan was suspended from the piston rod and a base line drawn by the pencil of the indicator upon the card. A sealed weight was then placed on the scale pan, and a new line drawn upon the card. If the two lines thus drawn were too near to each other, the wire of the spring was reduced in

cross section by a suitable tool. The indicators have also been tested very carefully under a steam pressure. They prove to be excellent instruments. An interesting report of this test, or rather series of tests, has been made by James B. Stanwood and Wilfred Lewis, but properly this report would be given in another place.

Indicator cocks have been attached to both ends of the cylinder of the engine, to the steam pipe near its juncture with the steam chest, and to the exit pipe of the small boiler about midway between the U-tube of the standard gauge and the thermometer. Indicators can readily be attached at those places and the pressure observed.

The Apparatus for Driving the Indicator Cylinders, described by Frank T. Sargent.

Two pulleys are fastened by set screws to the same shaft. The diameter of one is twenty-four inches, equal to the stroke of the piston of the engine, the diameter of the other is equal to the length of the diagram to be drawn on the indicator card. Both are one-fourth of an inch face and have grooves for strong, inelastic cords. About five inches from the crank end of the cylinder, there is placed a grooved carrier pulley, four inches in diameter. The top of this carrier, the top of the 24-inch pulley and the centre of a stud in the cross-head are in the same horizontal line, parallel to the piston rod.

A strong cord is fastened to this stud, carried over the 24-inch pulley to which it is so fastened that it can not slip in the groove, then around the carrier and back to the stud to which it is again made fast. Ordinarily, the 24-inch pulley is driven directly by the engine during the return stroke, and by stiff, quick acting springs during the forward stroke.

If from any accidental cause the speed of the engine should suddenly increase so much that the springs could not reverse the apparatus with sufficient rapidity, the cord running around the carrier pulley would enable the engine itself to reverse the apparatus and prevent accident to it. At either end of the cylinder and directly below the cocks to which the indicators are

fastened during an experiment are two carriers, each four inches in diameter, and one-half inch face, with three grooves. These carriers are driven during the return stroke by a short cord attached to the smaller of the pulleys on the shaft before mentioned. They are driven by a quick acting spring during the forward stroke. These carriers are readily attached to or disengaged from the paper cylinders of the indicators by short vertical cords having convenient hooks and rings. By means of this nicely constructed apparatus, which was made for the Institute by the Lowell Machine Shops, the paper cylinders of the indicators have a motion at all times proportional to that of the piston of the engine.

The Steam-Pipe, Valves, etc., were put in position by Walker, Pratt & Co., of Boston. A 3-inch pipe conveys steam from the producing boiler to the engine or to the small boiler as is preferred. A two and one-half inch wrought iron pipe, thoroughly jacketed with asbestos felting, carries steam from the small boiler to the engine, to the superheater, or to the exhaust pipe of the engine, as may be necessary.

A three and one-half inch exhaust pipe, also covered with asbestos felting, carries steam from the engine, the small boiler, or the superheater, to the calorimeter, the pipes used for heating the building or to the waste pipe.

No valves were used in these steam connections which were not carefully tested for leakage, under hydrostatic or steam pressure, by Mr. Barrus or myself.

Very great pains were taken to avoid leaky joints in the piping. If any joints proved leaky upon trial, the leaks were stopped by rust or red lead cement, or new joints were made.

The Brake for consuming the power produced by the engine, is of very simple construction. Blocks of whitewood press against the rim of the main pulley, surrounding or partially surrounding it, as circumstances require. Two long, strong chains encircle these blocks, to which they are firmly attached by wrought iron staples. A scale pan or weight box is suspended by those ends of the two chains from which the sur-

face of the pulley runs. The other ends of the two chains are fastened to a fixed support. By varying the weights in the weight box, the power consumed by the brake can be readily changed.

Adjoining the engine room and opening from it, is a large, convenient room, which has been fitted up for the use of the students while they are working up the results of experiments, or for similar purposes.

Numerous pieces of special apparatus have been provided by Mr. Dixwell, for special experiments, but it would be premature to describe them in this communication.

The ultimate object of our laboratory instruction and experiments is to make the students so familiar with the nature of steam, heat and work, that they will feel that steam and heat are their obedient servants, that they will neither dread thermodynamic power nor deal with it recklessly, nor give undue weight to the opinion of men who know no more about such things than themselves. It will give them increased confidence in the judgment of men whose greater experience in, and whose thorough study of, these things makes them competent advisers. They can also learn something about that most important of all questions connected with the use of steam or of machinery, what is practical economy?

Among the experiments of a general character, for which we are now prepared, may be mentioned those on the conversion of work into heat or of heat into work; on the capacity of different bodies for heat; on the change of bulk of solids, liquids and gases, under constant pressure, due to changes of temperature when it is attempted to keep the volume constant; on the relation between the temperature and pressure of saturated steam; on the total heats of superheated or saturated steam or of a mixture of steam and water; on the latent heat of fusion or of evaporation; on the transfer of heat, by radiation, conduction or convection, through different substances or through different thicknesses of a substance; on the cooling of gases by expansion; on the conductivity of fluids and solids; on the boiling and

melting points of different substances; on the condensation of steam; on resistance to boiling; on the comparison of quantities of heat; on the measurement of heat by evaporation; on the efficiency of heating or cooling surface. Most or all of these experiments might be conducted without much reference to the practical bearing of their results, but by judicious selection of the experiments and by carefully calling student's attention to their results, several of them might be conducted in one general experiment having for its object the solution of a practical problem. In this way we are able to solve some of the questions proposed to us by Mr. Dixwell, and other experiments of a practical nature.

Some of the practical problems which we can readily solve, relying upon the Chemical Department for assistance in the analysis of substances are; those on the efficiency and cost of operating pumps, feed water heaters, etc.; on the cost of production of steam in dollars, or in pounds of coal; on the percentage of combustible matter contained in the fuel; on the efficiency of furnace and boilers; on the waste of unburned fuel in the solid state; the waste of unburned fuel in the gaseous and smoky states; the loss of heat in the hot gas which escapes by the chimney; on the uneconomical effects of forcing fires; on the efficiency and evaporative power of boilers under various conditions of pressure or with different kinds of fuel, and the effects of bad draught upon the evaporative power; on the comparative value of different kinds of grate bars; on different methods of introducing the air necessary for combustion and dilution; on the comparative value of different styles of bafflers and bridge walls; on the most economical rate of combustion; on the comparative efficiency of firemen in charge of steam-boilers; on the comparative economy of detached furnace boilers; on the economy due to increased heating surface; on the evaporative power of boilers; on the loss of evaporative power due to bad draught; on the increase of evaporative power due to the direct action of the radiant heat of the furnace or to steam draughts; on the examination of boilers by hydrostatic

pressure or by internal and external surface examination; the examination of steam and water gauges, gauge cocks, low-water detectors, safety-valves and similar apparatus; on the obstruction to the flow of steam through pipes, produced by bends and valves, and by pipe friction; on the economy due to the covering of steam pipes with non-conducting substances; on the efficiency of steam heating apparatus; on the difference between the pressure in the boiler and the initial pressure in the cylinder; on the efficiency of the steam in the engine; on the rejected heat of the engine; on the useful work of the engine; its indicated power; its efficiency with various rates of lead, cut off, release or cushioning; its efficiency at different speeds; its efficiency under a varying load; and its comparative uniformity of speed, whether controlled by a variable cut off governor or by a throttle-valve govenor; its comparative efficiency with superheated or saturated steam, or a mixture of steam and water in a steam-engine, under varying circumstances of initial or back pressure; or when cutting off at different points of the stroke; adjustment of the eccentric and valves; on the adjustment of governors; on different kinds of piston packing; on cylinder and lubricating oils; on friction in the engine; on cylinder condensation.

Experiments already conducted on the economy of diminishing the leakage past imperfect steam-engine valves and piston packing have demonstrated the fact well known to experts, that the prevention of leakage is very important to users of steam-engines.

Other experiments of equal value intrinsically are those upon cylinder condensation, the economy of using steam at different grades of cut off, the use of superheated steam, the expansion of steam in the cylinder, and many others.

The object of some experiments would be to enable the students to become skillful in the manipulation of instruments used by engineers in testing steam boilers, engines and kindred apparatus. These experiments are so planned, that the defects resulting from the ignorance or carelessness of the experimenter,

will become very apparent to him when he comes to work up the results of the experiments.

The object of other experiments is to give the students experience in examining critically the instruments used in tests, making them familiar with their defects, enabling them to avoid some of the errors that inexperienced people are likely to make in their use, and to correct those other errors which of necessity exist in the best instruments.

Concerning the experiments on the critical examination of instruments used in tests, it ought to be said that most of the steam gauges, thermometers, and similar instruments that are to be found in the market are not intended by the manufacturers to be instruments of precision. Something which will tell what the steam pressure or the temperature is, in the rough, answers the purpose of a large majority of customers. These rough instruments being good enough for their purpose, they do not care to pay for more accurate, but at the same time, more expensive ones. But the makers of such apparatus manufacture a better class of instruments intended to be used by experts and others in various tests. These are much more expensive and are made with much greater precision. Engineers generally rely upon them for all ordinary purposes, and as often as they have reason to suspect that their accuracy has deteriorated, they are in the habit of sending them back to the makers to be readjusted.

But even the adjusted instruments are not sufficiently accurate to answer truthfully, nice scientific questions. Instruments suitable for such a purpose are very rarely wanted, could never be made profitably except upon order, and only then at very great expense by very careful men. Not many such instruments have ever been made, and when Regnault and other precise experimenters needed them, they were obliged to make them themselves. From the outset our laboratory was intended to be one in which practical experiments could be made in the ordinary way. Its most important use was believed to be to give young men skill in such kind of experimenting as would be of practical value. And while, as far as was possible, the

best apparatus to be had upon order in the American market was obtained, we have not supplied ourselves with that exceedingly precise apparatus which can not be bought.

The celebrated experiments by Regnault determined under very favorable circumstances, with instruments of extraordinary precision, the law which connects the pressure and temperature of saturated steam. As we can easily make saturated steam of any desired pressure, one instrument of precision, either of pressure or temperature, taken in conjunction with Regnault's law, would give us the means of examining critically each of our instruments for measuring pressure or temperature, and of forming a connected scale which would practically convert them into instruments of precision; for our apparatus is delicate and sensitive, and so far as we know now, indicates the same pressure or temperature whenever subjected to the same influences.

In the former part of this report the statement was made that our indicators had been tested very carefully. It was thought to be desirable to make a critical examination of the standard test gauge, the thermometers and the indicators, under the conditions of ordinary working. Accordingly, the three instruments were attached to the exit pipe of the small boiler, at points whose positions have been described in a former part of this paper. It will be remembered that the gauge was graduated to correspond with a mercurial column; that the thermometers were graduated by comparison with a standard thermometer and by calibration, and that the indicator springs were adjusted very nicely by means of sealed weights hung upon the piston rod. We had no special reason for doubting the accuracy of either of the instruments nor that of one more than that of another; and the examinations already made have satisfied us that they were, practically speaking, excellent instruments in excellent condition; but they had not been compared with one another, and had not been compared with a common standard. We were able to compare them with one another, and that we proceeded to do. After several preliminary experiments, it was decided on account of the rapidity with which the thermometer

showed changes of temperature to take the thermometer temporarily as a standard. By observing the pressures indicated by the gauge and the indicators, we should be able to judge of the accuracy of the instruments according as they corresponded with or deviated from Regnault's law. It was decided to make six experiments, three of which would compare both the gauge and the indicator numbered 562, and three others, which would compare both the gauge and the indicator numbered 567, with the thermometer assumed to be a standard. The indications of the gauge were observed by Mr. Thomas Hibbard, who made the following report:—

"Six experiments have been tried to test the gauge and compare it with Regnault's tables. In the first place, steam is blown through the small boiler which is used as a steam drum, in order to expel the air and heat up the apparatus. The valves are then closed; thus confining a certain quantity of steam in the drum, which rapidly condenses. The pressure is thus lowered below the atmospheric pressure, 14.7 pounds per square inch, and the temperature below 212° F. Everything is now ready for the experiment. Steam is admitted from the large boiler by opening the admission valve by degrees. The steam being throttled, the temperature and pressure in the drum rise slowly. The operator who reads the thermometer gives the word at every 9° F., commencing at 212° F. Just at those instants the pressure given by the gauge and indicator, is observed and recorded. The gauge was read to tenths of a pound, as nearly as could be judged by the eye. When the pressure in the drum rises so as to be nearly that in the boiler, the admission valve is opened to its widest extent. Then the steam pressure is allowed to rise gradually in the producing boiler, until it reaches about seventy-five pounds. The pressure in the drum, which is in free communication with the boiler, rises about the same. When the thermometer reads 320° F, corresponding to this greatest pressure, the admission valve is closed, thus shutting up the steam in the drum. Condensation now takes place, the temperature and pressure fall, and the readings are taken for

every 9°, beginning with 320° F, down to 212° F. To accelerate the condensation, the fire-doors and dampers of the drum were opened, thus causing a draught of cold air through the tubes. When the temperature falls to 212° F. and the pressure to about 0 pounds, the experiment is complete.

"In three of these experiments the barometer was read and the corresponding deduction or additions calculated for the height of the mercury column above or below 29.92 inches, or 14.7 pounds pressure. The mean readings of the gauge for each three experiments were ascertained, and the differences between them and Regnault's corresponding pressures determined. Now with the temperatures for abscissæ, i. e., distances measured horizontally, and these differences as ordinates, or vertical distances, two curves were constructed. The straight horizontal line represents Regnault's law of pressures and temperatures, while the constructed curves in the same manner show, upon the assumption that the thermometer is correct, the errors of the gauge. It was noticed that, when the gauge was tapped, it started ahead a little, not exceeding two-tenths of a pound, however, thus showing that there was some friction in the mechanism of the gauge. Most of the pressures registered by the gauge were within one pound of Regnault's pressures, while but few of them differed by two pounds. Most of the readings were less than Regnault's, seeming to show that either the gauge did not record as high pressures as it should, or that the thermometer read too high temperatures. The curves also indicate this, since they lie almost wholly below Regnault's line. There are many sources of error in such an experiment, but we hope by repeating them a number of times, and taking the mean reading, to get a table of corrections for the gauge."

The diagrams from indicator No. 562, were taken by Mr. J. B. Stanwood, an extract from whose report is as follows: —

"The test that was made on indicator No. 562 was to determine if the pressures indicated by the instrument corresponded to the pressures calculated by Regnault in his table of temperatures and pressures for saturated steam. These tables

were taken for our standard; they have an increase in the temperature column of 9°, that is, pressures are given corresponding to every 9° from 32° F., upwards. A Huddleston thermometer was used, together with the indicator, and both were placed on the steam pipe leading from the small boiler. In using the indicator, steam was kept in the cylinder until a few seconds before the line was to be drawn; it was then all shut off, and that which remained in the cylinder passed off into the air. Then steam was readmitted, and the line was taken just as the mercury passed the 9° mark. The reason for shutting off the steam and readmitting it, was in order to overcome any friction which might retain the piston in its place. At the beginning of the experiment steam was allowed to pass through the small boiler from one of the large boilers until all the air had been blown out and the boiler had been well heated up. Then the boiler was cut off from the external air, and from the large boiler, the steam that remained in it was allowed to condense until its temperature was about 210° F., then the steam was admitted slowly from the large boiler, and for each 9° passsd through by the mercury a line was taken by the indicator, showing the difference of the steam pressure from the atmospheric pressure; the first reading was taken at 212° F., and the last at 320° F. When the experiments first commenced, the pressure in the large boiler was about thirty pounds per square inch above the atmospheric pressure; as soon, however, as the pressure in the small boiler was the same, the pressure was allowed to increase in the large boiler. After the temperature was greater than 320° F., the small boiler was entirely shut off from everything, and the pressure then decreased by the condensation of the steam. Thus three experiments were made and six cards taken, three for ascending pressures and three for descending; from these cards the results of the experiments are obtained.

"After the experiments had been performed, two curves were constructed to show the variation of the indicator from the tables. One of these curves was for ascending pressure, the

other for descending. A horizontal line was taken to represent Regnault's curve of pressures and temperatures; the temperatures were measured off on this line as abscissas, while the difference between the table pressures and the observations were taken as ordinates. In order to obtain the two curves only from the six different observations, the mean observation for each temperature was taken for both ascending and descending pressures, and the differences between these and the tables were taken as ordinates. The curves were below Regnault's line, until they arrived at the temperature of about 248° F., and were then above Regnault's line, the ordinates steadily increasing between 248° and 320° F. If, now, instead of trying to make our instrument more accurate we construct a table taken from experiments, we can correct for errors and obtain better results than otherwise."

The diagrams from indicator No. 567, were made by Mr. Wilford Lewis, who says in a part of his report: — "In these experiments the indicators seemed to have an almost constant error of about eight-tenths of a pound below the pressure as given by Regnault's tables. This may be due partly to the pressure of the atmosphere being about 14.7 pounds, or to a constant error in the reading of the thermometer."

Without going so much into the details of the results of these experiments as to make them very tedious, it is enongh to say that neither the indicators nor the gauge gave always the same pressure for a given temperature. Take, for instance, the pressure given by the gauge when the thermometer read 266° F., as the temperature was rising. The different readings of the gauge at that temperature were as follows: —

Experiment.	*No.* 1.	*No.* 2.	*No.* 3.		*No.* 4.	*No.* 5.	*No.* 6.
Gauge rising	24.25	24.4	24.1	Gauge rising	24.	23.5	24.8
" falling.	24.4	25.7	24.	" falling	23.9	24.	24.
Ind'r 562 rising	25.5	25.	24.6	Ind'r 567 rising	23.3	23.2	24.
" " falling	24.6	26.5	24.2	" " falling	24.1	24.2	23.9

The barometric pressure was noted in some of these experiments but not in others; but the discrepancies could not be ac-

counted for by changes in the atmospheric pressure. Some of the gauge readings differed as much as 2.2 from others, and as there must have been a reason for these differences, I concluded to plot the different experiments, and to ascertain, if possible, the causes which produced the discrepancies. They were plotted according to the system previously indicated; Regnault's law being represented by horizontal lines, horizontal distances representing degrees of temperature on a scale of ten to the inch, and vertical distances representing, on the assumption that the thermometer is correct, the error of the instrument on a scale of one-half pound to the inch.

All indications made while pressures were rising, were indicated by circles. All those made while pressures were falling, were indicated by diamonds. All made by indicator 562 were represented by black ink; all made by indicator 567, by blue ink; all made by the gauge by red ink. The first set of diagrams showed the errors in all the pressures observed with any one instrument on a sheet by itself. This set resembles a chaos of spots. The second set showed the comparative indications of all three instruments in any one experiment.

In the diagram of the first experiment, the gauge showed almost the same indications with rising as with falling pressures, but the indicator showed from one-quarter pound to one pound more pressure when rising than when falling.

In the diagram of the second experiment, the gauge at any temperature seemed to differ from the indicator about as much with rising as with falling pressure; but both the falling curves were crooked or warped in a remarkable manner.

The diagram of the third experiment resembled that of the first except that the falling curves had changed about equally the angle which they made with the rising curves. The diagrams of the fourth, fifth, and sixth experiments also showed that some cause or causes apparently affected both instruments at the same time.

A third set of diagrams was now made, showing the errors in all the rising pressures observed with any one instrument, on

separate diagrams from those exhibiting the errors in the falling pressures.

A careful comparison of these diagrams, with the recorded details of the experiments, led to the belief that one or more of six causes might have given rise to the discrepancies.

If the thermometer was slow to indicate changes of temperature; if the barometer changed considerably during the progress of an experiment; if saturated steam of a given pressure sometimes varied a little in temperature; if what we had supposed was steam had been a mixture of steam and air; if the steam which we had supposed was saturated had been superheated by any means, as by wire-drawing or by radiation of heat into it; if the indications had been incorrectly observed or recorded; these anomalies might have occurred. Some of these apparent causes could not be seriously entertained. The others were more likely to have acted, and it was determined to ascertain by further experiment whether the thermometer was dilatory; whether the steam was superheated; or whether the errors of observation need be very large.

The first new experiment was arranged on the supposition that the thermometer was dilatory. It was easy to make the indicated pressure vary about one and one-fourth pounds by changing the circumstances of the experiment.

A second new experiment was arranged to show still more clearly that the thermometer was dilatory. The gauge was taken as a standard and a slight current of steam was made to pass through the drum for three-quarters of an hour. During this time the pressure in the producing boilers was pretty constantly twenty-eight ponnds, and the pressure in the drum very precisely twenty-five pounds by the test gauge. The temperature of the steam as indicated by the thermometer with its bulk in steam was very constantly 269.25° F. This temperature is what would have been expected, had the pressure been about twenty-six pounds per square inch.

As there was no water in the drum, a relief valve was suddenly opened, reducing the pressure as quickly as possible to

one pound per square inch. Observations were then taken every five seconds. A slight current of steam passed constantly through the drum, while the pressure was maintained at one pound per square inch by throttling the admitted steam. The first temperature observed was 252° F. After about one minute, the temperature rose to 253.5°. This is the temperature of saturated steam of a pressure of about seventeen pounds per square inch, while the real pressure was only one pound. This dilatory behavior became exc ting. The readings taken every five seconds became monotonous. The students became hoarse with calling readings. After ten minutes the thermometer had fallen only to 240°; after thirty-eight minutes, to 221°; after forty-six minutes to 219.25°. To hasten the cooling still more, if possible, cold water was pumped into the drum. It did not cover the orifice through which the steam was entering. The temperature remained at 219.25° so long that our time and patience became exhausted. We then increased the pressure as rapidly as was considered safe, to 24.5 pounds per square inch, and the thermometer then read 268°. Throughout the remainder of the experiment, when the gauge indicated twenty-five pounds per square inch, the thermometer indicated 269°. We anticipated 269.25°, but as one-quarter on the scale was a small quantity, this difference was not suprising.

It was concluded from this experiment that the record of the thermometer was approximately true, but that the steam was superheated during the time that the gauge indicated one pound pressure. It was finally concluded that we should get the most reliable experiments by starting with steam at about atmospheric pressure in both boiler and drum, and gradually increasing the pressure at a very slow rate, comparing the indications of each of the instruments before mentioned with an accurate mercurial column, so arranged that its indications could be corrected for the temperature of the mercury in the column.

An extended series of experiments on cylinder condensation at different grades of cut off, with a pressure of seventy pounds

of steam in the boiler, has been partly concluded. The records of these experiments show not only the total heat of the steam which left the boiler, but also, approximately, the total heat in the steam at different points of the stroke, between the cut off and release, and, finally, the heat rejected by the engine and carried by the exhaust steam into the calorimeter. Each experiment with saturated steam at a given point of cut off, is supplemented by an experiment with superheated steam having the same initial pressure and cutting off at the same point. The results already arrived at are very interesting, and when the series is concluded I shall have valuable information to report to you. I am

Very respectfully yours,

CHANNING WHITAKER,

In charge of the Mechanical Engineering Department.

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*Sears David . . "
Shaw, Mary S. . . "
*Skinner, Francis . "
*Stetson, Joshua . "

Thayer, Nathaniel . "
Thorndike, John H. . "
Tobey, Edward S. . "
*Turner, J. M. . . "

*Upton, George B. . "

Walcott, J. H. . . "
Wales, Geo. W. . . "
Wales, T. B. . . . "
Wales, Miss . . . "
*Whitney, Joseph . "

ASSOCIATE MEMBERS.

Adams, James . . Charlestown.
Allen, James T. . . W. Newton.
Ames, Isaac . . . Boston.
Amory, T. C. . . . "
Anderson, Luther W. Quincy.
Appleton, Thos. G. . Boston.
Atkinson, Chas. F. . "
Atkinson, Wm. P. . "
Austin, Edward . . "

Bacon, John . . . "
Barber, Lyman L. . Charlestown.
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Batchelder, John M. Cambridge.
Beal, James H. . . Boston.
Bender, Richard W. "
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Bigelow, G. F. . . "
Bigelow, Jacob . . "
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Bond, W. S. . . . "
Boott, William . . Boston.
Bourne, William . . "

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Bowditch, Wm. I. . "
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Cabot, Samuel . . "
Carey, A. C. . . . "
Carpenter, Geo. O. . "
Carruth, Charles . "
Clapp, Wm. W. . . "
Clarke, E. H. . . "
Clinch, John M. . . "
Cummings, Nath'l . "
Curtis, Frederick . "

Dana, Edward A. . "
Danforth, I. W. . . "
Danforth, James H. . "
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Davis, Barnabas . . "
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Dunklee, B. W. . . "

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Fuller, Horace W. . "

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Goddard, Benjamin "
Goddard, Nathaniel "
Grandgent, L. H. . "
Guild, Chester, Jr. . "
Guild, Henry . . "

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Hall, Charles B. . . "
Hall, Thomas . . . "
Hamblet, James . . "
Haven, Franklin. . "
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Heard, John T. . . "
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Holmes, Jabez S. . "
Holmes, O. W. . . "
Homans, C. D. . . "
Houghton, Charles . "
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Hyde, Henry D. . "

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Jackson, Patrick T. . "
Jasper, Gustavus A. . "
Jenks, Lewis E. . . "

Kehew, John . . . "
Kendall, Edward . . "
Kneeland, Samuel . "

Lamson, Chas. D. . Boston.
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Lanza, Gaetano . . "
Lawrence, A. A. . "
Lee, Francis L. . . "
Lee, Thomas J. . . "
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Lewis, Wm. K. . . Boston.
Lincoln, F. W. . . "
Little, James L., Jr. "
Little, John M. . . "
Lothrop, Sam'l K. . "
Lowe, N. M. . . . "
Lowell, John . . . "
Lyman, Theodore . Brookline.

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Marshall, H. N. F. . "
Mason, Robert M. . "
May, F. W. G. . . Dorchester.
May, John J. . . . "
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McMurtrie, Horace . "
McPherson, W. J. . "
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Montgomery, Hugh . Boston.
Moore, Alex. . . . "
Morse, John T. . . "
Morse, Samuel T. . "
Munroe, William . "

Nichols, James R. . Haverhill.
Norton, Jacob . . Boston.

Ordway, John M. . W. Roxbury.

Page, Edward . . Boston.
Page, W. H. . . . "
Parsons, Wm. . . "
Paul, J. F. . . . . "
Peabody, O. W. . . "
Perry, O. H. . . . "
Philbrick, Edward S. "
Philbrick, John D. . "
Pickering, E. C. . . "
Pickering, H. W. . "
Pierce, S. S. . . . "
Plumer, Avery . . "
Pope, Edward E. . "
Prang, Louis . . . "
Pratt, George W. . "

Pratt, T. Willis . . Boston.
Putnam, J. P. . . "

Quincy, Edmund . Dedham.
Quincy, Josiah . . Boston.

Revere, Joseph W. . "
Rice, Alexander H. . "
Richards, R. H. . . "
Ritchie, E. S. . . . Brookline.
Robbins, James M. . Milton.
Robinson, J. R. . . Boston.
Rotch, Benj. S. . . "
Royce, H. A. . . . "
Ruggles, John . . "
Runkle, John D. . Brookline.
Russell, LeBaron . Boston.

Salisbury, D. Waldo "
Sawyer, Edward . Newton.
Sawyer, Timothy T. Charlestown.
Sears, Philip H. . . Boston.
Shedd, J. Herbert . "
Sherwin, Thos. . . Dedham.
Shimmin, Chas. F. . Boston.
Shurtleff, A. M. . . "
Sinclair, Alex. D. . "
Smith, Chauncy . . Cambridge.
Snow, S. T. . . . Boston.
Sprague, Chas. J. . "
Stackpole, G. W. . "
Stevens, Benj. F. . "
Storer, H. R. . . . "
Storer, Jacob J. . . "
Strater, Herman, Jr. . "
Stuart, Chas. F. . . "
Sturgis, John H. . "

Sullivan, Richard . Boston.

Thompson, Wm. H. "
Thornton, J. Wingate "
Tufts, John W. . . "
Tuxbury, Geo. W. . "

Upham, J. B. . . "
Urbino, S. R. . . . "

Walworth, J. J. . . "
Ware, Chas. E. . . "
Ware, Wm. R. . . "
Warren, Cyrus M. . Brookline.
Warren, Geo. W. . Boston.
Warren, Joseph H. . "
Warren, Sam'l D. . "
Waters, C. H. . . . Clinton.
Waterston, R. C. . Boston.
Watson, R. S. . . Milton.
Watson, Wm. . . Boston.
Weld, Stephen M. . "
Weston, David M. . "
Whipple, Edwin P. . "
Whitaker, Channing Lowell.
Whitman, Herbert T. Boston.
Whitmore, Wm. H. . "
Whiton, David . . "
Wilder, Marshall P. Dorchester.
Williams, H. W. . . Boston.
Winthrop, Robert C. "
Wood, John F. . . "
Wright, John H. . . "
Wyman, Morrill . . Cambridge.

Zalinski, E. L. . . Boston.

Greene.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

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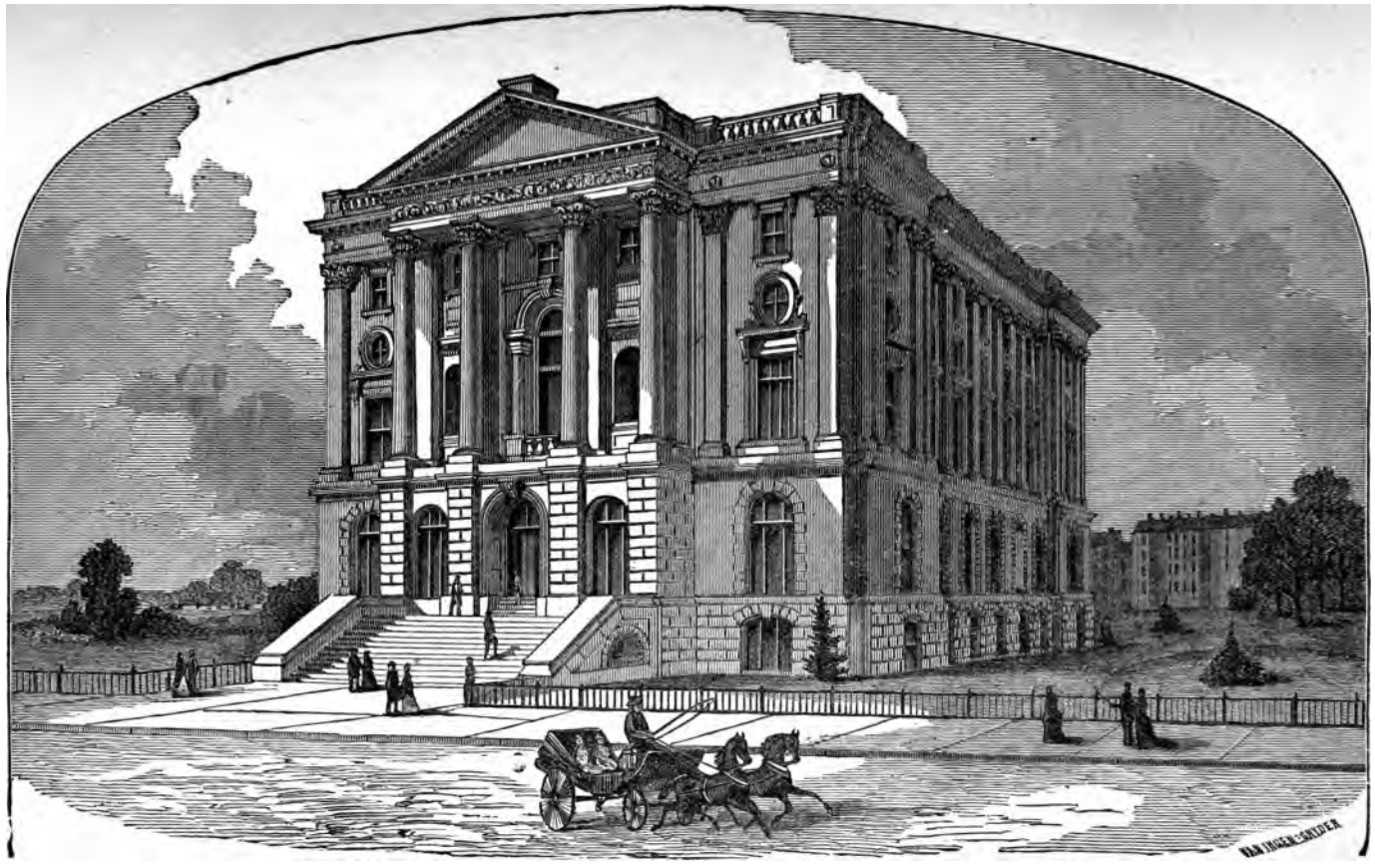
PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1875.

BOSTON:
PRESS OF A. A. KINGMAN.
1876.



INSTITUTE BUILDING.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1875.

BOSTON:
PRESS OF A. A. KINGMAN.
1876.

Extracts from Acts of the General Court of Massachusetts, in relation to he Massachusetts Institute of Technology.

Act of Incorporation. "William B. Rogers [and others named], their associates and successors, are hereby made a body corporate, by the name of the MASSACHUSETTS INSTITUTE OF TECHNOLOGY, for the purpose of instituting and maintaining a Society of Arts, a Museum of Arts, and a School of Industrial Science, and aiding generally, by suitable means, the advancement, development, and practical application of sciences in connection with arts, agriculture, manufactures, and commerce."

Chapter 183, *Acts and Resolves of* 1861.

Grant of Public Lands. "When the Massachusetts Institute of Technology shall have been duly organized, located, and established, ... there shall be appropriated and paid to its treasurer, each year, on the warrant of the Governor, for its endowment, support, and maintenance, one third part of the annual interest or income which may be received from the fund created under and by virtue of the 130th chapter of the Acts of the 37th Congress, at the second session thereof, approved July 2, 1862 [giving Public Lands to the States in aid of instruction in Agriculture, the Mechanic Arts, and Military Science and Tactics]. . . . . Said Institute of Technology, in addition to the objects set forth in its Act of Incorporation [as above quoted], shall provide for instruction in military tactics."

Chapter 186, *Acts and Resolves of* 1863.

Power to confer Degrees. "The Massachusetts Institute of Technology is hereby authorized and empowered to award and confer degrees appropriate to the several courses of study pursued in said Institution, on such conditions as are usually prescribed in universities and colleges in the United States, and according to such tests of proficiency as shall best promote the interests of sound education in this Commonwealth."

Chapter 247, *Acts and Resolves of* 1863.

CONTENTS.

President's Report vii
Secretary's Report xvii
Graduates in 1875 xxx
Department of Philosophy 1
Department of English and History 7
Department of Modern Languages 9
Department of Military Science and Tactics 21
The Lowell Course of Practical Design 34
The First Year's Course in Free Hand Drawing 36
The First Year Mechanical Drawing 39
Department of Descriptive Geometry, Stereotomy, and Drawing . 44
The Instruction in Physiology and Hygiene, and Zoology . . 49
The Instruction in Physical Geology and Geography . . . 51
The Course in Palæontology 54
The Department of Geology 58
Bridge and Roof Construction 65
Theoretical and Applied Mechanics 72
Department of Mechanical Engineering 76
Department of Chemistry 78
The Course in Mining Engineering 81
Mining Expedition to Nova Scotia 88
Lowell Free Courses for 1874–75 94
Abstracts of Theses presented by Graduates of 1874–75 . . . 105
Fall River Water Works, by Samuel E. Allen 105
Lattice Girder Bridge, by H. K. Burrison 109
Lattice Girder Bridge, by C. A. Church 107
Salem Water Works, by Frank S. Dodge 107
The Iron Bowstring Girder over the Charles River at Waltham, by Edgar S. Dorr 108
Tunnelling, by Edward A. W. Hammatt 109
Brookline Water Works, by Edward A. Handy . . . 110
The Holyoke Dam, by Wm. F. Huntington 111
The Lawrence Dam, by W. F. Sargent 112

On the Coefficient of Expansion of Dry Saturated Steam in an unjacketed cylinder, by James H. Head 114
The Construction of Gear Teeth, by Thomas Hibbard . . 115
The Crank as a Means of converting Reciprocal into Circular Motion, by J. Austin Knapp 117
Governors, by Wilfred Lewis 118
Cylinder Condensation, by Thomas D. Plympton . . . 120
Steam Pumps, by F. T. Sargent 121
Locomotives, by J. B. Stanwood 123
Salt, by Moses D. Burnet 125
The Stamps of Lake Superior compared, by C. W. Goodale . 125
Burleigh Tunnel Ore, Colorado, by B. A. Oxnard . . . 125
Working of an Ore of Silver and Lead, from Newbury, Mass., by Wm. H. Shockley 134
Treatment of a Silver Ore, from Silver Islet, Wood's Location, Lake Superior, by H. L. J. Warren 139
Designs for the buildings for a City Water Works, by Amos J. Boyden 140
Anthracene Pressings, by Leonard P. Kinnicutt . . . 142
Report of a Series of Experiments with a Holtz Machine, by S. J. Mixter 143
The Empire of Austria, by Wm. A. Prentiss 144
The Department of Architecture 145
Architectural Problems 151
Appendix 159
Corporation for 1875–76 159
Committees to Visit and Inspect the several Departments of the School 160
Officers of Instruction 162
Conditions of Admission 164
Regular Courses of Instruction 165
Architectural Department—Books 175
" " Photographs 179
" " Drawings, Prints, and Lithographs 181
" " Casts 185
" " Stained Glass 185
" " Tiles, Terra Cotta, Models, etc. 196
Alumni of the Institute 200
Members of the Society of Arts. 206
Preparation for Admission 210
List of Lowell Courses 216
Plans of Floors of Institute Building 219

PRESIDENT'S REPORT.

To the Corporation of the Institute:—

Your attention is respectfully invited to the following reports and matters relating to the various departments of the Institute for the current year, the tenth since the establishment of the School.

The only changes in the corps of Instruction during the year have been the resignations of S. Edward Warren, C. E., Professor of Descriptive Geometry, Stereotomy and Drawing, and Edward K. Clark, S. B., Instructor in Mechanical Drawing.

Instructor William E. Hoyt has been given charge of the Stereotomy, Instructor Wells of the Descriptive Geometry, and Assistants Francis T. Sargent and J. Austin Knapp, of the Mechanical Drawing in the department of Mechanical Engineering.

Attendance. The whole number of students in attendance for the year 1874–75, was 288; a decrease of 22 from the preceding year. Of the 73 applicants for admission to the first year, at both the June and September examinations, 29 passed without conditions at an average of 73 per cent.; 26 passed with conditions at an average of 51 per cent.; and 18 failed to pass. Based on the mathematics alone these averages were 81 and 60 per cent. Of those admitted 15 did not join the class.

These reductions left a class of 40 new men, and one repeating, 36 of whom were regular students, and 5 special. It will be noticed that 25 per cent. of the applicants failed to pass, and that over 25 per cent. of those who passed did not join the class, mainly on account of the continued hard times, as was afterwards ascertained. Sixteen new students entered the second year, 8 without, and 8 with conditions. The average age of the class entering the first year was 17 years and 10 months.

Preparation for Admission. The suggestions made on pp. 210-215 are respectfully submitted to teachers by the Faculty, in order to make the work of preparation as definite as possible. The poorest preparation has usually been upon what are properly the grammar school studies. It is not overlooked that public policy usually demands that the High School must accept such preparation as the Grammar Schools can furnish, and should not therefore be held wholly responsible for these studies. Still it is hoped that the High Schools may be able to remedy the defect, in part, by requiring a careful revision during the early part of their course of such portions of the subjects as have been pointed out. Moreover, it cannot be denied that a large proportion of the High Schools continue to maintain classical departments for the purpose of fitting students for admission to College at a cost altogether disproportionate to the end gained. It would be far more economical for each town to support the few students who enter College from its High School, at a good classical school, and thus save the time and energies of the best teachers for other subjects of growing importance, as the modern languages, mechanical and free-hand drawing, chemistry and physics with laboratory practice, and such elements of Natural History as the teachers of each school may be best fitted to give; and if, in addition to the above changes, Latin could be rationally studied for about two years as part of the required course for graduation, these schools would be vastly more useful to the large numbers whose education ends here, and would also be better able to prepare

students for admission to scientific and technical schools, and that without in the least departing from their legitimate work. Much of the work now done in our first year should be done in these schools, and could be, if the changes indicated were made, without much increasing the average age at which students now enter the Institute. The gain to the High Schools as well as to us can hardly be over-estimated.

Degrees. One hundred and twenty-six students have completed prescribed courses of study, and degrees have been given in years and departments as follows: —

	1868	1869	1870	1871	1872	1873	1874	1875	Total.
Civil Engineering	6	2	4	8	3	12	10	10	55
Mechanical Engineering .	1	2	2	2	1	1	4	7	20
Mining Engineering . . .	6		2	5	4	2	1	6	26
Architecture						1	1	1	3
Chemistry		1	1	2	3	6		1	14
Physics								1	1
Science and Literature . .	1		1			1	2	2	7
Total	14	5	10	17	11	23	18	28	126

For the names of the Alumni, with present residence and occupation, so far as known, see Appendix, pp. 200–205.

Your attention is particularly invited to this list, as furnishing the best evidence of the estimation in which the work of this School is held by the public. We have every reason to be gratified by the record of the graduates of our first ten years.

Lowell Free Courses of Instruction. In the establishment of the School of Industrial Science of the Institute, two distinct objects were contemplated: —

First, regular four years' courses of study having special ends in view, and leading to graduation; and

Second, courses of instruction for those who could not command all their time, to be given mainly in the evening, and under such conditions as would secure the attendance of those having the proper preparation to profit by them.

Thus far in the history of the school this second department has been supported by the Trustee of the Lowell Institute. Each year, in the month of October, the courses to be given are announced, with the conditions of attendance.

These courses, which have always been free, and open to both sexes, are given on pp. 216–218.

During the year instruction in Physics has also been given to the Sophomore Class of Boston University, partly by lectures, partly in the Rogers Laboratory. This instruction has been entirely separate from that given to our own students, and has not in the least degree interfered with either the work or discipline of the school, while the department has been very sensibly benefitted by the increased income; and we anticipate the same good results for the chemical department during the coming year, from the same source. Judging from past experience, we shall be justified in opening more generally the lecture-rooms and laboratories of the Institute for the instruction of outside classes, and advanced special students of either sex, in such departments as have the means and space to give it. The advanced instruction in many of the studies, particularly in the later years, is given to small classes, which would not be incommoded by the admission of such advanced students.

I respectfully ask that you will give this subject the attention which it appears to me to deserve.

Lowell School of Industrial Design. The number of students in this department was 25, the same as in the preceding year. Eleven of these students were young men, and fourteen young women. Three years have passed since the establishment of this department, and it can no longer be considered an experiment. It will be seen from Mr. Kastner's report that fifteen students have been granted "Certificates of Proficiency," and nearly all of them are employed by some of the leading Mills in New England. Many samples of goods from designs made by the pupils, or graduates of this school, are already in the market and have been received with favor.

During the past year a much larger variety of designs have been made. Students have been encouraged to work in special directions, and the results have been marked by greater breadth and character. The execution, almost without exception, even among the newest pupils, is remarkable, and is the best possible evidence of the value of the system pursued, and the skill of the teacher. While the designs may not in all cases exhibit the highest type of excellence or taste, it must not be overlooked that they are the work of beginners and must be judged as such.

In this respect also there will be great improvement when students fail to find desirable places before thoroughly completing the prescribed three years' course of study. Lately painting on tiles, porcelain and furniture has been introduced with every prospect of success. It is expected that gradually the range of the school will be widened, and thus give scope to a greater variety of taste and employment. The foundation is well laid for the building up of a great school of practical Industrial Art. It will aid in educating the public taste and increase the demand which it is intended to supply. I earnestly commend this department to your confidence and support.

The Mining and Metallurgical Laboratories. These laboratories have become so important an element in our courses of Mining and Metallurgy, and are besides so novel in such a connection, that it may not be uninteresting to briefly review them in their origin and progress thus far in the history of the department. From the beginning, vacation excursions to mining regions for the purpose of study by teachers and pupils have constituted an important element in the instruction; and in this systematic way many of the more important centres in the United States and Canadas have already been visited. Not only in each locality have the geology, the minerals, the mode of their deposition and extraction, and their metallurgy been studied, but the opportunities have been used to make collections of cabinet specimens, and particularly of the ores of each

locality sufficient for quantitative study in these laboratories. The most important of these excursions took place in the summer of 1871, when a party of professors and students, twenty-one in number, and nearly all belonging to the departments of Mining and Metallurgy, visited some of the most important points in Missouri, and afterwards spent some six weeks in studying all the more developed centres in Colorado and Utah. It was during this excursion, while observing the wrecks of fortunes strown all over the territories, that the thought occurred to us, that much of this waste was due to a want of practical skill joined with scientific knowledge, and that the opportunity for experimenting upon comparatively large quantities of ores must be furnished to our students during their course, as a part of their laboratory work. After disbanding the party I visited San Francisco, and had the good fortune to make the acquaintance of some skillful practical metallurgists, who were making the examination of ores a specialty, and had built up laboratories for ore-dressing, on about the scale we needed. But the processes were detached, and no attempt was made to represent the best forms and kinds of machinery in use at that time in California for the reduction of gold and silver ores.

I had the good fortune to meet Professor William P. Blake, who not only gave me the aid of his scientific and practical experience, but introduced me to the firm of H. J. Booth & Co., of the Union Iron Works, of San Francisco. Mr. I. M. Scott, of this firm, entered fully into the matter, designed the five-stamp battery now in our laboratory, made drawings for the placing of this and the connecting pieces of apparatus, and also furnished us full illustrative drawings of one of the largest and most complete mining mills in California. The sum charged was not much above the cost of the drawings; the firm making a generous contribution to our laboratory.

These steps would have been fruitless if I had not been so ably and enthusiastically supported by Professors Ordway and Richards. The furnaces in the Metallurgical laboratory were designed by Professor Ordway and built under his direction,

while the Mining laboratory has reached its present state of progress almost entirely through the ability, practical skill, and untiring energy of Professor Richards. Thus, what was a conviction has become a practical reality, and the entire credit for the existence of these novel laboratories is due to the professors whose unfaltering faith in success has made them possible.

It is not supposed that the student's experience, gained in these laboratories in handling comparatively large quantities of ores, will supersede the necessity of that wider and more definite experience which can only be gained at the works; but it is claimed that he is made aware by his failures, if not by his successes, of the difficulties he is sure to encounter in actual practice, and is taught not to despise mere practical skill, but to proceed with great caution, and to enter upon constructions involving large expense only after careful preliminary investigation, such as the experience gained in these laboratories especially qualify him to undertake. Full abstracts of two theses are given, to show more clearly than any statement can do the kind of problems assigned and the labor involved.

The pressing need of these laboratories is more space to properly arrange the apparatus and to accommodate the increasing numbers of students taking these courses.

The Fourth Year Chemical Laboratory. The contents of this laboratory were burned on the evening of November 11, 1875. It has been thoroughly refitted, and is now, owing to the skill of Professor Wing, a model of neatness and convenience. The opportunity has been improved to secure a more commodious balance room, and to make the space at the disposal of the department as available as possible. All the apparatus and materials destroyed have been renewed, except the large collection of analyzed substances, which it will take time to replace.

The Mechanical Laboratory. My last report contained a full account of this laboratory by Prof. Whitaker. Another year's experience has furnished additional proof of its value to students in steam engineering. Some of the evidence will be found in the abstracts of theses by students in this department. We still need a small shop fitted with the usual machine tools.

Department of Architecture. I need only to ask your attention to the report relating to this department, and particularly to the large and varied collections available to both teachers and students to illustrate the several courses of instruction. The instruction in this department did not begin till the fall of 1868, and it may be of interest to you to know how it is now considered by one of our best students, who, after completing the course here in 1874, went abroad to continue his studies. We are often asked whether the advantages for architectural study are not far greater abroad, and it is also to answer this question that I quote a few sentences from a letter of one well qualified to give an intelligent opinion: —

"One thing I am firmly convinced of, and that is that any one who thinks of leaving the Institute and coming abroad at the end of his first year, ought to be dissuaded from it — by main force. He is infinitely better off where he is if he did but know it. In one thing especially the Institute has a great advantage — the freedom and character of the library and collections are so much superior to the advantages we have here. Of course there is an admirable library and fine collections at the School of Fine Arts, but they are not at all times accessible in that they are so far distant from the several *ateliers*, and are protected by bands of red tape. So a student has to depend entirely on the library of his *atelier*, which is at best a small and often an ill-chosen one."

"Another great advantage one has at the Institute is that he has those framed drawings by Brune, Calinaud, Escalier, Tissandier, and Létang always at hand. Here at the *atelier* we have nothing whatever to refer to, and when a drawing has to be rendered it has to be done by guess-work and on general principles each time."

"At the *expositions* of the second class [comprising the students who have been only three or four years at the *École*], I think I am safe in saying that the average draughtsmanship is not so good as the average of

the second year at the Institute. Another advantage is the more practical light in which things are looked at."

It is also true that there has been during the past few years a marked improvement in architecture in this city, making it a more desirable place for the building up of such a school. The student will not fail to find in Boston and vicinity good examples of all kinds of such public and private buildings as he may hereafter be called upon to construct.

It gives me great pleasure to be able to present this satisfactory evidence of the character and success of the department.

Department of Military Science and Tactics. The drill hall and gymnasium, which the aid of friends[1] has enabled us to build, together with some changes in the details of the instruction, seem to have finally settled all difficulties. I am extremely happy to be able to report that the department is in an excellent condition, and that the best discipline is maintained without any more difficulty than any other department meets in securing the same efficiency. I think the present status is substantially supported and approved by all; and it is simple justice to Lieut. Zalinski to say that while enforcing the necessary regulations with strictness, he has retained the respect of his pupils, and won the esteem of all by his unselfish devotion to their interests.

[1] Subscriptions in aid of the Drill Hall and Gymnasium: —

George B. Emerson	$500	E. B. Robins	$25
Wm. B. Rogers	400	Theodore Lyman	25
Kidder, Peabody & Co.,	350	Charles H. Dalton	25
James L. Little	200	R. C. Greenleaf	25
Ernest W. Bowditch	150	T. T. Bouvé	25
Bent & Bush	100	M. L. Bradford	25
Wm. C. Peters	100	Joseph P. Ellicott	25
M. D. Ross	100	Frost & Adams	25
J. D. Runkle	100	E. Collamore	25
Henry L. Pierce	75	Charles W. Galloupe	25
John H. Reed	50	Wm. B. Spooner	25
Thomas F. Edmands	50	George P. Denny	20
Henry W. Williams	50	Wm. V. Hutchings	20
Mellen, Williams & Co.	50	Surg.-Gen. Dale	20
J. Iasigi	50	Mrs. Daniel Treadwell	10
Wm. E. Baker	50	J. H. Blake	10
Rufus S. Frost	50	From "Friends"	360
John C. Ropes	50		
George W. Simmons	50	Total	$3,240

The Restaurant. In my last report you were informed that we were trying the experiment of establishing a restaurant, which, if reasonably successful, we should attempt to put on a more permanent basis. This has been done at an expense of about $900.[1] We have now a dining room, a lunch room, a kitchen with store rooms, and caterer's rooms, all suitably furnished. Full dinners are served for thirty-five cents, and board by the week for $3.50. I am fully satisfied that it is the duty of the Institute to maintain this restaurant as a means of promoting the health of students, and of reducing their necessary expenses.

Conclusion. Upon the whole, the year's work has been satisfactory. The gain has mainly been in the improvement of the laboratories, and making the experimental side of the instruction more systematic and thorough. All we need to make the progress in the future as marked as in the past ten years is more space. Some important work has never been properly done on this account. The department of Industrial Chemistry is almost entirely destitute of the proper room for large operations, and work in Organic Chemistry is only done at the expense of the comfort, if not the health, of all in the building. But I must refer you to reports of departments for a fuller statement of their several needs.

I close by thanking teachers and students for their hearty coöperation in the work of the year.

JOHN D. RUNKLE, *President.*

[1] Subscriptions in aid of the Restaurant:—

Joseph S. Fay	$150	James L. Little	$50
S. P. Ruggles	100	Wm. Endicott, Jr.	50
J. M. Forbes	100	E. R. Mudge	50
John Cummings	100	H. P. Kidder	50
E. B. Bigelow	50	From "Friends"	100
H. B. Rogers	50		
M. D. Ross	50	Total	$900

SECRETARY'S REPORT FOR 1874–75.

There have been held during the year twelve meetings of the Society of Arts, at which various subjects of practical importance were discussed.

At the meeting of *Nov. 12, 1874*, Mr. Robert B. Forbes read a paper on the "Tracks for Atlantic Steamers," as a report of his doings as representing the Institute in conference with the Committee of the Social Science Association in regard to the "Maury Lanes." He concludes by saying "Now that we have a steamer leaving Europe and North America on the Atlantic every five or six hours, no amount of argument should be necessary, and no pains omitted, to induce all to adopt the Maury Lanes. Unless steamers adopt some definite lines for going and returning, recent disasters show that size, speed, and elegance of ship may not save from collision accompanied by great loss of life."

Within a few months the loss of over four thousand human lives shows the necessity for more means to save life, and better arrangements to prevent accidents from fire, collision, etc. He advocated more and better boats, rafts, life-buoys, mattresses and belts, and various buoyant contrivances carried by the ship herself; all of these, however well-contrived, may yet be useless if the crew are not rendered familiar with their use by frequent drilling. Any properly constructed raft, well supplied with food and water, would be very likely to save its passengers if in the track of steamers crossing the Atlantic, as the lines, if

adopted, would be only a hundred miles or so wide; a sailing vessel, too, disabled, would know where to send her boats to be sure of meeting a passing steamer. The ship herself should be made invulnerable to ordinary ocean casualties, by double bottom as far as the load line, iron decks, water-tight compartments, boiler spaces cut off from other compartments and from coal bunkers below the load line, donkey engine and boiler far away from ordinary casualties of the main machinery, and pumps so fitted that steerage passengers could be used for their working. In other words, make the ship a life-boat.

He advocated better means of detaching boats from their tackle, the Ammen wooden raft, or the Perry or Monitor raft of vulcanized rubber, the swinging davit, and the substitute of the centre-board for a keel in boats. Means for throwing a line two hundred or three hundred yards should be on all passenger ships and men-of-war.

At the same meeting, Mr. H. P. Langley read a paper on "Artificial stone, and its uses," illustrated by specimens. He confined his remarks to that made by the use of hydraulic cements, lime and magnesia, including the Ransome, Frear, Beton-Coignet, and Sorel processes. Stone made by any of these processes has not come into general use in this country as building material; a few buildings, in Boston and vicinity, have been erected wholly or in part of the Frear stone, and the Beton-Coignet has been used to some extent in foundations, piers, etc.; a stone embodying strength, durability and elegance can be made from Portland or the best American cements and pure silicious sand. Many useful and ornamental articles for domestic use are made by the Sorel process. He also exhibited and explained several grinding machines.

Dec. 10. Mr. John C. Hoadley, of Lawrence, read a paper, illustrated by numerous carefully made drawings, on the "Indicator Diagram and its Interpretation."

The indicator, an instrument invented by James Watt, to show the operation of steam in his engines, was the forerunner of a large class of philosophical instruments for noting and

recording vibrations, from the pulsations of an infant's heart to the throes of an earthquake, and velocities, from that of a gentle breeze to that of a rifle projectile or a ray of light.

The diagram, credited to the same inventor, in which forces are exhibited to the eye under the form of curves, by abscissæ proportional to times, spaces, or volumes, and ordinates proportional to pressures, stresses, strains, or any other similarly related magnitudes, is applied to almost all subjects to which the human mind directs its attention.

The indicator is a small, subsidiary, reciprocating engine, attached to the cylinder of a steam engine, or other similar machine, sharing the pressures, expansions, and forces of the chamber with which it communicates; and expending the work developed in its own cylinder in compressing a spring, and in giving motion to a pencil or marking point, which traces on a slip of paper, moving under it with a known velocity, a curved line which, properly interpreted, discloses much concerning the action of the steam or other fluid in the engine, the adjustment of valves, the adequacy of ports and passages, the tightness of packing, the dryness of the steam, the quantity expended per unit of force, and other important points bearing on the question of economy.

After describing the best indicators in use, he showed how the diagrams were made, and how interpreted; he took up the subject mathematically, analyzing observations of his own made during several years, and drew from them practical lessons of great value.

Dec. 24. Mr. George Woods, of Cambridge, made a communication, illustrated by a model worked by steam and water, on his new process for drying lumber and other materials in a natural and rapid manner. The old process of drying lumber in the open air requires from six to ten years, and the consequent loss of time and capital stimulated inventors to devise quicker processes, and various drying rooms have accordingly been in use, with more or less success. In the usual method of forcing a current of air through a room heated to about 150°

Fahr., from partial ventilation the drying was found to be imperfect, causing irregular shrinkage and consequent inequalities in the wood; the steam pipes were carried under the lumber, and the air forced to pass over it, drying the outside first, the interior remaining damp from the air being saturated with moisture. He uses steam pipes under the lumber, but the moisture which is driven by the heat into the containing chamber, instead of being carried off with great loss of heat by the ventilating current, is condensed by cold water constantly running in pipes through the chamber into a grooved channel below, by which it escapes. The moisture is thus gradually, uniformly, and constantly withdrawn from the wood, which dries regularly, without strain on the outside or cracking on the inside. He claims that he can accomplish in six days what the ordinary drying room requires three weeks for, and with much better results; he saves three quarters of the time and utilizes all his heat, and the moisture once out of the wood can not get back.

Mr. N. M. Lowe made some remarks, illustrated by photographs, on the "Leaning Tower of Pisa," adding his testimony in support of the general belief that the tower was not built so, but has sunk from imperfection in the foundation, aided by the yielding character of the soil. Its height is nearly two hundred feet, and its diameter thirty feet; it leans from the perpendicular about thirteen feet, but, as the centre of gravity falls within the base, the structure will not fall unless there be further sinking of the foundations.

Mr. H. P. Langley made some remarks on various mechanical devices, which have of late years made their appearance in this community, achieving for their inventors a short-lived success, and for their users and purchasers vexation and pecuniary loss, with especial reference to steam boilers.

Jan. 14 and 28, 1875. Mr. H. McMurtrie presented portions of a wooden casing which had surrounded a steam pipe at a hotel in this city, showing how wood may be charred by steam used for heating purposes at a distance of an inch from the iron

pipe. Many mysterious fires may owe their origin to this cause.

Mr. Thomas S. Hall, of West Meriden, Conn., made a communication, illustrated by an extensive series of working apparatus, on his system of automatic electric railway signals, for the prevention of accidents from head and rear collisions, misplaced switches, open drawbridges, and railroad and highway crossings, dispensing with the steam whistle, and lessening the number of workmen required, an automatic electric power taking the place of careless and forgetful human agents. The usual way has been to allow a certain interval of *time* to elapse before one train is permitted to succeed another. This system is exceedingly defective, as, if an accident or detention occur, the engineer behind has no reliable means of knowing where the preceding train is; even the electric telegraph, from the carelessness or inexperience of operators, may, as in a recent case, fail to give warning in time to prevent collision.

Mr. Hall's system substitutes for this an interval of *space*, trains being kept a mile apart as indicated by his automatic signals, rendering collision impossible, avoiding the multiplication of tracks, and allowing the much more frequent despatching of trains. The block system, used in England, requires a great number of men day and night, and many accidents have happened under it.

In Mr. Hall's system the road is divided into sections of about a mile in length, at the ends of which are placed two signals, one red, to denote danger; the other blue, signifying caution. When all is right, the red signal should be out of sight, and the blue signal exhibited. As the train passes the first, it raises it, at the same time removing the blue signal, which is about 1000 feet ahead. The red signal then prevents the next train from approaching too near, while the blue signal shows the engineer that the red signal has been displayed. About 600 feet beyond the blue signal, the train reverses the signals of the previous section, or those of a mile and a third back, thus allowing the next train to approach.

Only two instruments are employed, one to enable the train to close an electric circuit, and the other to display a signal to show when this circuit has been closed. He showed his system in operation, of full size, explaining the electrical mechanism; it was seen that a red signal always remains up after a train until it is a mile and a third distant, and that, if all is right, the engineer should see neither the red nor the blue signal, but only the empty windows of the signal frames. The battery, which should consist of about twenty cups to the mile, is kept on an open circuit, except when a train is passing, and the consumption is thus comparatively small.

Should a wire break, or any accident happen, the only result will be that the caution signal will remain visible, and the engineer be thus notified to take care.

The system has been introduced on many of the principal railroads of the country, and on several in this vicinity.

February 11. Mr. A. W. Sprague, of Quincy, read a paper on "Automatic Regulation of Heat and Ventilation," exhibiting operative models of a draft-damper for furnaces and stoves, and also of a ventilator, both working automatically from the heat of the room.

The present devices for controlling drafts of heaters by what are known as "*back* checks" are known to be a prolific source of disease; by them the free exit of the poisonous anthracite gases is prevented, and these are forced out, and pass along with the heated air up into the apartments warmed. He thinks that the combustion should be controlled by *front* drafts, and that the opening and closing of dampers should be automatic, operated by the heat of the rooms warmed. Several devices have been in use for this purpose, worked by the direct heat of the furnace, but such a variable element could not be depended on. In this device the power which works the damper is controlled by a small cylinder of confined air placed in the apartments warmed, which, like an engineer, shuts or opens the damper when the heat of the room goes above or below the point at which the instrument is set. His ventilator operates

upon the same principle, ensuring a pure air, relieving from all watching of drafts, and preventing waste of fuel. They were exhibited in successful operation at the meeting, worked by the heat of the room.

Several members of the senior class of the school, in the department of Mechanical Engineering, then read papers describing their experiments with various pieces of apparatus, to determine some of the properties of steam on a practical scale. The subjects illustrated were superheaters, the Corliss engine, calorimeter and surface condenser, steam gauges, thermometers and pyrometers, and indicators, bearing upon various mechanical, physical, and chemical problems of practical importance.

Feb. 25. Mr. Alfred R. Payne, of Lynn, read a paper, illustrated by a large number of models and diagrams, on "Boiler Explosions," showing the causes of the disasters, and the position assumed by the fragments.

1. Among faults in *original construction*, he drew attention to bad welds, to collapsed flues from insufficient supports, to large boilers improperly stayed, to bad shaped boilers, and such as had no compensation for a large man-hole in the shell. 2. From *frequent and ill judged repairs.* 3. *From weakness, in ordinary working*, principally from external and internal corrosion, especially due to leakage. 4. From *shortness of water.* 5. From *over pressure*, from inoperative or absent safety valves.

For the four years ending June 1870, there were in Great Britain 219 boiler explosions, by which 315 persons were killed and 450 wounded; the greater part of these would have been prevented by proper inspection; very few were caused by shortness of water. He mentioned also many American explosions, including that of the ferry boat Westfield, in 1871. In 1870, there were in this country 118 explosions, by which 326 men were killed and 227 injured; in 1871, there were 93, with 313 killed and 281 injured; in 1874, there were 105 explosions, with 183 killed and 199 injured.

March 11. Mr. Charles W. Spurr read a paper, illustrated by an extensive series of specimens, on patent papered wood-hangings, to the improvement of which he had devoted several years.

About forty years ago the invention of veneering led to the use of thin layers of the valuable woods as a substitute for the solid wood. Attempts to apply veneers to house walls, on cotton or canvas supports, did not prove successful. Then the sheets were laid directly upon plastered walls; they were cut from a log revolving against a horizontal knife in continuous sheets; it was necessary to put them on green, and the ends consequently cracked on drying, while the centre moulded; they were so tender that it was very difficult to handle them, and the process fell into disrepute.

His improvement consists in covering the back of each sheet, as it comes from the cutting machine, with fine, strong Manila paper; this gives a surface to which the wood firmly adheres, and which clings everywhere to the plastered wall in all its irregularities. The paper is applied to alternate sides of the wood, so that corresponding edges come together, forming a regular pattern, without waste of material or useless expense. The wood and paper are united with pure flour paste, and are applied to the wall with the same. Steam and furnace heat have no effect upon them; frost and dampness will not injure them; they will neither shrink nor swell, and can be washed; and they strengthen the plastered wall, and prevent its cracking.

The rolls are cut by a rotary veneer-cutting machine, revolving on two different centres, cutting in the form of an ellipse; it makes from six to fourteen revolutions per minute, gaining in power what is lost in speed; it cuts sheets twelve feet long, the width varying with the size of the log. Walnut and other open-grained woods are cut one hundred and twenty-five sheets to the inch, while maple is cut to two hundred. They have been tried in this vicinity sufficiently to test their durability.

March 25. Mr. Horace McMurtrie read a paper, illustrated by diagrams and models, on the "Governing Principles of the Screw Propeller, practically considered."

If we imagine the shaft of the propeller, with a screw on its extremity, to be a bolt with a thread on its end, and the surrounding water to be a solid immovable nut, it will be understood, in a general way, how by the revolution of the shaft and screw, the vessel is propelled forward or backward.

In the application of power to the propulsion of vessels, part of the effect is lost by the instrument of transmission. In the common paddle wheel this loss is made up of *slip* plus *oblique action* — in the feathering wheel, of *slip* plus *drag* — and in the screw, of *slip* plus *friction* of the surface on the water. The surface of a screw blade may be supposed to be generated by a line revolving around a cylinder at right angles to the axis, at the same time moving along it. The "pitch" of a screw is the advance made by it in a complete revolution in the direction of the axis; in actual practice the full convolution is never used, but only a fraction, say one tenth of the entire pitch for each blade, the number of which varies from two to four. By changing the angle of the blade to its axis, the pitch can be increased or diminished.

The main loss of effect is due to *slip*. Water being movable, a portion of the power of the screw is lost in imparting motion to this water in an opposite direction to the advance of the vessel. The recession of this watery fulcrum is called the *slip*, which is measured in per centums of the speed of the screw. He illustrated the nature of slip, by the action of a man pushing a cart in loose sand. As the man pushes the cart forward, the sand, which is the fulcrum of the power, yields backward to the pressure of the feet, and the cart, instead of advancing the length of a step for each step, which it would do were the man pushing on rock, would advance only the complement of the length of the step, after deducting the distance receded by the sand. Each step, whether on sand or on rock, causes the man an equal expenditure of labor; in the latter

case, the labor being all utilized in giving motion to the cart, while in the former a portion is uselessly expended in giving motion to the sand.

The resistance of the screw may be increased, and the slip thereby diminished, other things being equal: 1, by increasing the diameter of the screw; 2, by diminishing the pitch; 3, by giving the screw an expanding pitch from the anterior to the posterior edge of the blade; 4, by increasing the fraction of the pitch used; 5, by employing two equal and similar screws, one under each quarter; 6, by increasing the depth of immersion.

April 15. Mr. A. D. Blodgett, a student of the Institute in the department of Mechanical Engineering, read a communication on an "Automatic Electric Burglar Alarm," of his own invention.

This he explained, and exhibited in operation attached to doors and windows, so arranged that the opening of one or the raising of the other, would not only ring an alarm, but, in connection with an electric annunciator, indicate the room in which the burglarious attempt was made.

His device combined both the open and closed circuits. It is very simple, there being no clock work to be wound up, as is sometimes the case with closed-circuit alarms, and there is no machinery to increase expense or to render repairs necessary. As there are three wires running to each door and window, a burglar would not know which to cut and which to connect, which he might in a closed or open circuit; as all the wires come through the same aperture in the casing, it would be almost impossible to tamper with them successfully. If all three wires are cut the alarm is sounded.

Mr. Martin then exhibited in operation, and described a "type writer," a machine to supersede the pen in manuscript writing.

In size and appearance it resembles a sewing-machine; writing is performed by touching small round keys, like those of a piano, arranged in four rows of eleven each, and may be done by one or both hands; each key, on the top of which the letter

or sign is indicated, by depression with the finger causes its letter to be printed on the paper by means of a lever. Any one who can spell can write with it, and any quality or length of paper can be used, from three to eight inches wide. The type receives ink from a moving ribbon, which can be used for months without being re-inked, and with proper usage will last a year. Its work is as legible and as uniform as print; its average speed is twice that of the pen, and one good operator is as good as two expert penmen for all purposes except book-keeping and writing in books. For lawyers, reporters, copyists, clergymen, the blind, and for those whose hand writing is illegible from age or any other cause, such a machine is of great value. Any one with two weeks' practice can write with it faster than with a pen. By using copying ink and the manifold process, with thin papers, twenty copies can be written at a time. For teaching spelling and punctuation in schools it is of advantage, and its use would be like play to a child.

April 29, and May 13. Mr. George B. Dixwell read a paper, illustrated by diagrams and tables, on "Cylinder Condensation," and the means of suppressing it, in steam and vapor engines. The conclusions he arrived at after a large number of experiments, extending over several years, and verified in the Mechanical Laboratory of the Institute.

His first object was to show that this condensation was of great importance as a difficulty to be overcome, and to do this he examined the published experiments of Chief Engineer Isherwood, about one hundred in number, made on fifty different engines.

Since the time of Watt, engineers have been trying in vain to realize all the theoretical advantages of working steam expansively, and it was supposed that cylinder condensation was the cause of their failure; the loss from this cause was shown, at about a half cut off, to be about forty per cent. of the steam utilized, thus disappearing more than one half of the gain expected from expansion; clearance, back pressure, and friction would take off more, so that the gain would be very little; with

a shorter cut-off it is worse, and there may be absolute loss instead of gain.

Being satisfied of the importance of cylinder condensation, the next question was how to suppress it, and to ascertain what had been or could be done by steam jackets, and the system of compounding. He showed that the saving by jackets was really very small.

He explained how he thinks it comes to pass that cylinder condensation is different at each cut-off, that the actual amount should be many times the equivalent of that directly due to the conversion of heat into work and radiation, and that the condensation in the higher pressure cylinder of a compound engine should be much less at the same cut-off than that in the low pressure cylinder.

He then explained how he had come to the conclusion, which he thought entirely new, that the action of the metallic surface is *cumulative*, causing the total condensation to be several times that caused at each stroke by the conversion of heat into power, and by radiation. Even in the best compound engines there is a loss by condensation of 20 per cent. of the steam utilized; he showed how their performance may be increased some 35 per cent. by an expenditure of 10 per cent. of heat, and this by superheating. He explained how the vapor of water is, unlike air, one of the best radiators and absorbers of heat, and how a film of steam converted the polished metallic surfaces into an energetic radiator. Steam may be superheated sufficiently to balance the radiation and the heat converted into work, without fear of its carrying into the cylinder a temperature injurious to the working parts. The expense of such superheating is trifling, cylinder condensation is suppressed, and the gain is about 25 per cent. in compound engines.

There how been no elections during the year. Five members have died during the year. Messrs. Hammatt Billings, Samuel Hooper, James Lawrence, Charles G. Putnam, and N. B. Shurtleff; twenty-three have resigned, and six have been

dropped for non-payment of fees. The list now comprises 63 life, and 200 associate members.

The attendance at the School of Industrial Science for the year has been 288, as follows: Resident Graduates, 21; Regular Students of 4th year, 35; of 3d, 45; of 2d, 55; of 1st, 36; — Students not candidates for a Degree; 4th year, 15; 3d, 13; 2d, 24; 1st, 5; Architectural Students, 26; Students in Practical Design, 25, of whom 14 were females. Total 288, of whom 12 were graduates of other Institutions. Of these, about five-sixths were from Massachusetts, principally from Boston and its vicinity; — from other New England States, 17; viz.: from Maine, 7; New Hampshire, 3; Vermont, 2; Rhode Island, 2; Connecticut, 3. From other States, there were from New York, 9; Ohio, 7; Illinois, 6; Pennsylvania, 5; Indiana, 4; New Jersey, Minnesota, and California, 2 each; Tennessee, Kentucky, Michigan, Iowa, Nebraska, Colorado, British Provinces, Japan, Canary Islands, 1 each; Hawaiian Islands, 5.

Thirty-four professors and teachers have been connected with the school, and, as usual, several advanced students have rendered assistance in the laboratories and in surveying. The fees from students have amounted to about $47,000, a decrease of $3000 from the previous year.

The class in the School of Design has been full, and eminently successful. For details, see the Report of Mr. Kastner, on page 34.

The Lowell Free Courses for the year were as follows:

I. *General Chemistry.* Twenty-four laboratory exercises of two hours each, on Wednesday and Saturday afternoons at 2½ o'clock, by Professor Nichols, beginning Saturday, Nov. 21.

II. *Qualitative Analysis.* Twenty-four laboratory exercises of two hours each, on Wednesday and Saturday afternoons at 2½ o'clock, by Professor Nichols, beginning Saturday, Nov. 21.

III. *Practical Geology of the United States.* Eighteen lectures, on Tuesday and Friday evenings at 7½ o'clock, by Dr. T. Sterry Hunt, beginning Tuesday, Nov. 17.

IV. *Lantern Projections.* Eighteen lectures on the use of the Lantern as a means of illustration in teaching, on Wednesday and

Saturday afternoons at 3½ o'clock, by Professor Pickering, beginning Wednesday, Nov. 18.

V. *Elementary French.* Eighteen lessons, on Monday and Wednesday evenings at 7½ o'clock, by Instructor Jules Luquiens, beginning Monday, Nov. 16.

VI. *Modern Philosophy from Descartes to Hegel.* Eighteen elementary lectures, on Monday and Wednesday evenings at 7½ o'clock, by Professor Howison, beginning Monday, Nov. 23.

VII. *Elementary Principles of Mechanism.* Eighteen lectures for machinists, on Tuesday and Thursday evenings at 7½ o'clock, by Professor Lanza, beginning Tuesday Dec. 7.

Open to both sexes over eighteen years of age; applicants to apply in their own handwriting, stating age, occupation and previous preparation.

The Corporation has held six meetings during the year.

At the meeting of April 14, 1875, it was voted that the students of the Boston University may receive instruction in Chemistry at the Institute on payment of a certain sum to the Department.

At the same meeting it was voted that the Professorship of Geometry, Stereotomy, and Drawing be vacated at the end of the school year.

At the meeting of June 9, 1875, it was voted to confer the Degree of Bachelor of Science on the following students, who had complied with all the conditions:

Allen, Samuel E. . .	Fall River . .	Dept. of Civil Engineering.
Burrison, H. K. . . .	Boston . . .	" " "
Church, Christopher A.	New Bedford .	" " "
Dodge, Frank S. . .	Beverly . . .	" " "
Dorr, Edgar S. . . .	Mt. Auburn . .	" " "
Edes, William C. . .	Bolton . . .	" " "
Hammatt, E. A. W. .	Newton Centre .	" " "
Handy, Edward A. . .	Barnstable . .	" " "
Howes, Clar. L. (1873)	Hanover . . .	" " "
Huntington, Wm. F. .	Springfield . .	" " "
Sargent, Welland F. .	Sedgwick, Me. .	" " "

Head, James H. . . .	Brookline . .	Dept. of Mechanical Engin'ing.
Hibbard, Thomas . .	W. Roxbury .	" " "
Knapp, J. Austin . .	Hanover . . .	" " "
Lewis, Wilfred . . .	Philadelphia, Pa.	" " "
Plimpton, Thomas D. .	Walpole . . .	" " "
Sargent, Francis T. . .	Malden . . .	" " "
Stanwood, James B. .	Cincinnati, O. .	" " "
Burnett, Moses D. . .	Syracuse, N. Y.	Dept. of Mining Engineering.
Goodale, Chas W. . .	Hudson . . .	" " "
Oxnard, Benj. A. . .	Jamaica Plain .	" " "
Shockley, Wm. H. . .	New Bedford .	" " "
Warren, H. L. J. . .	Boston . . .	" " "
Webster, Wm. R. . .	Philadelphia, Pa.	" " "
Wrinkle, L. F. J. (1870)	Lee	" " "
Boyden, Amos J. . .	Foxboro' . . .	Architecture.
Kinnicutt, Leonard P. .	Worcester . .	Chemistry.
Mixter, Samuel J. . .	Boston . . .	Physics.
Arnott, James L. . .	Thompsonv'e, Ct.	Science and Literature.
Prentiss, Wm. A. . .	Holyoke . . .	" "

The subjects of the Theses, and abstracts of the same, will be found on p. 105.

The progress of the School in the various departments will be found in the reports of the President and Professors.

SAMUEL KNEELAND, *Secretary.*

Boston, Oct. 9, 1875.

DEPARTMENT OF PHILOSOPHY.

To the President: —

During the year just closed, the changes in the course of study proposed at the end of the preceding one have been matured and put in operation. By alterations in the course for the school at large, my work with the regular students of *all* departments has been limited to two lectures a week during the whole of the First Year, and three a week during the first half of the Fourth Year. The changes in the Department of Philosophy itself, have amounted to carrying its leading subject a half-year backward, so that it now begins at the opening of the Second Year. In this way, the time allotted to the study of the Modern Systems has been extended, so that it now covers the Third and Fourth Years entire. The particulars of the Course as it now stands may be gathered from the last catalogue. Details of the work done in the two sections of my department are herewith submitted.

I. THE WORK WITH ALL REGULARS.

First Year's Class. During the first half-year, there were lectures and exercises twice a week on the Classification and Analysis of Terms, and the Structure and Analysis of Sentences. During the second half-year, the same number of lectures was given upon the Rudiments of Logic, including the Classification of Propositions — their Notation, Reduction, Opposition, Conversion, and Permutation — and the Elementary

Principles of Inference. As this was our first attempt at teaching Deductive Logic to First Year men, it is worth while to state that the experiment has been quite successful. At the annual examination in May, the class proved themselves to be well acquainted with all the general forms and principles of deductive inference, and showed a creditable skill in detecting the ordinary fallacies. But to secure the best results from the work now assigned to the First Year, it is desirable that we shall have a better preparation. For this reason, I would call the attention of the Faculty to the recommendation made in this connection last year, and would ask that it be adopted and put in operation when the next class is admitted; namely, that all candidates for the First Year's class be required to pass an examination in the Analysis of Sentences and the Classification of Terms.

Fourth Year's Class. During the first half-year, a course of three lectures a week was given to this class upon the following topics: the Elementary Principles of Inference; the Idea and General Divisions of a Philosophy of Science; and the Nature of Induction, with an account of its Recognized Methods. The lectures were accompanied by a study of Mr. Fowler's text-book on Inductive Logic. The interruption of our work at the middle of the preceding year, made it necessary to take part of this year's time to bring up the lost topics; consequently, the subjects proper to the Fourth Year had to be presented more briefly than our regular plans contemplate. With the next class, I shall be able to carry out the course in the Philosophy of Science as laid down in the catalogue.

II. THE WORK WITH STUDENTS OF PHILOSOPHY.

In the department proper of Philosophy, there have been this year nine students — three regular and six special — an increase of four over the year preceding. The changes involved in bringing the course of study for this department into the form now given in the catalogue, have ranked all the regulars as

students of the Third Year. Of the specials, three took the philosophical studies of the Third Year, and the remaining three the course in Psychology belonging to the Second Year. These last read with me the more important parts of Mr. Jardine's recent treatise on the *Psychology of Cognition*, which, including as it does a very good sketch of the various theories of Perception from Descartes to Kant, gave them a valuable introduction to the whole field of philosophy.

The regulars and specials of the Third Year have covered the ground assigned in the catalogue. They have thoroughly read the following matter: —

Descartes' *Method*, and his six *Meditations*, entire;
Spinoza's *Ethics*, in outline;
Leibnitz's *Monadology*, *New System of Nature*, *Nature of the Soul*, and *Doctrine of a Universal Spirit*, entire;
Locke's *Essay*, in its most important parts, with Cousin's Critique of the same;
Berkeley's *Principles of Human Knowledge*, entire;
Hume's *Inquiry Concerning Human Understanding*, — the first eight sections.

In addition to making and studying notes of my explanations and criticisms, the class have read from Schwegler's *History of Philosophy* the accounts of the systems of Descartes, Geulinx, Malebranche, Spinoza, Leibnitz, Locke, Berkeley, and Hume, together with Stirling's notes on the same, and Ueberweg's accounts of most of these systems. On Berkeley, they have read, besides, Fraser's *Introduction*, and the *Prolegomena* and *Notes* (by Ueberweg and others) contained in Krauth's edition of the *Principles*. The results of their examinations have been very gratifying. Specimens of the papers used during the year are subjoined.

EXAMINATION ON LEIBNITZ.

1. Brief narrative of Leibnitz's career. His principal works, etc.

2. Items of agreement between Leibnitz and the Cartesians, and between Leibnitz and Spinoza.

3. Points of vital difference between Leibnitz and both of these.

4. What specific difficulties felt in both of the previous systems was the Theory of Monads intended to overcome? In how far does it succeed? What difficulties does it leave still unsettled?

5. Sketch the Theory of Monads. [Definitions — Exposition of their Nature, Relations, and Gradations — the "City of God."]

6. State Leibnitz's peculiar argument for God's existence.

7. Name and state the Three Working Principles of Leibnitz's System.

EXAMINATION ON BERKELEY.

1. Titles of Berkeley's principal works, with the date and burden of each.

2. Clear and full outline of his *Principles*, including its parts, and the contents of each part.

3. What, according to Berkeley, constituted the currently received principles? What, exactly, does he mean by the expression, "principles of knowledge"?

4. What are the principles that he proposes to substitute? With what general school does his fundamental principle connect him?

5. In what sense, and in what sense only, does Berkeley deny the existence of Matter? Rebut the common objection of "plain absurdity," charged upon his view.

6. What, exactly, is Berkeley's doctrine a theory concerning? What point against the common theory does he unquestionably establish? What depth hid in the common view does Berkeley's fail to appreciate?

7. How, precisely, does Berkeley's theory differ from Malebranche's "Vision in God"?

8. Sketch Berkeley's several arguments for the insubstantiality of Matter? What does he mean by his perpetual reiteration that matter is merely "phenomenal," or that its "*esse* is simply *percipi*"? Into what contradiction, or at any rate obscurity, does he fall, when pressed with the apparent *discontinuity* which his doctrine introduces into na-

ture? What ambiguity here comes to light in Berkeley's use of the term *idea?*

9. State Berkeley's argument for the existence of God.

10. What does Berkeley think he has *demonstrated* concerning Matter and concerning God?

11. Criticise each of his arguments for the insubstantiality of Matter. Show that, in two of them, he practically begs the question, and how; and that, in the other two, he strikes wide of the mark, or, as the logicians say, commits *ignoratio elenchi.*

12. Reflect on Berkeley's argument for God's existence, and then endeavor to state *completely*, all the principles it implies. Give an estimate of it in the light of your results.

13. What, in the second grand division of his treatise, does Berkeley unquestionably succeed in showing?

14. What does he attempt to show in the Third Part? What estimate would you put upon his success here, and why?

15. What permanent contribution may Berkeley be said to have made to Modern Philosophy? In whom, however, did a conscious insight into this view first arise?

16. Compare Berkeley's doctrine with the Cartesian; show their difference upon formal points, but their essential identity in failing to solve the problem of intercommunion between Subject and Object.

17. Compare Berkeley's view with Spinoza's; show from what standpoint it has the apparent advantage over the latter of preserving the identity of the Individual Soul and its distinctness from God; but show, also, from what standpoint it loses this advantage entirely. Point out the contradiction in Berkeley's thinking, which is here implied.

18. What remarkable passages in the *Principles* seem to penetrate to a philosophy which, while thoroughgoing idealism, would fathom the insight, deeper than Berkeley's, contained in the common view? Why cannot this deep view be credited to the *Principles* as a system?

ANNUAL EXAMINATION, MAY 29, 1875.

Write a connected sketch of the history of Philosophy, from Descartes to Hume inclusive, giving the systems of Descartes, Spinoza, Leibnitz, Locke, Berkeley and Hume. Be especially clear upon the following matters: —

1. The essential and distinguishing principle of the whole modern philosophic method.

2. The relations of the several systems to each other, and to the modern philosophic movement as a whole.

3. The exact statement of those points in the several systems which the ordinary reader is pretty sure to misapprehend, but an error about which will prevent any real insight into the systems.

4. The characterization of each system as a whole; the statement of the points upon which it has attained to permanent views; and the criticism of its errors and failures.

5. The tracing of Cartesianism through its various attempts to solve the Problem of Certitude consistently with its preconceived principles; including, particularly, the extensions of Descartes' doctrine made by Geulinx and Malebranche.

6. In the case of Leibnitz, the conception of the Monads, the Gradations of Existence, and the Three Principles of Thought.

7. In Locke's case, the exact point rendering him of lasting significance in the history of philosophy.

8. In Berkeley's, to show just how he differs from the ordinary view, just what he means by his "Idealism"; and to refute the vulgar objections to his theory, though criticising it.

9. In Hume's, to be full upon his critique of Causality, and his application of its results to the doctrines of Providence aad Moral Obligation.

Respectfully submitted,

GEO. H. HOWISON.

DEPARTMENT OF ENGLISH AND HISTORY.

President Runkle:—

I hereby transmit through you to the Government of the Institute the following account of my classes and lessons during the past school year.

To the second class, I gave a course of lectures on the history and literature of the latter half of the Eighteenth Century. Attendance on these lectures was compulsory, but early in the term, owing to the pressure of their scientific studies the time assigned for writing up notes was taken away. A good deal of voluntary writing was, however, done by various members of the class, and a considerable number gave a voluntary attendance on a continuation of the course through the second term.

To the third class, I gave a course of lessons on the history and text of the U. S. Constitution, with such references to English constitutional history as time allowed. Attendance on these lectures was compulsory and at the close of the term the class was examined on the text of the Constitution, but time enough was not allowed for more extended study of the subject out of the class-room.

During the second term nearly the whole of the class gave a very regular and constant voluntary attendance on a course of lectures on the Elementary principles of Political Economy and its connections with History.

At the request of a majority of the members of the fourth class, I read with the whole class some of the more important chapters in Prof. Parsons' work "The Laws of Business for Business Men," especially those on the law of contracts, a subject which was assigned to the students in "Science and Literature" only. Study was not compulsory, but the students generally bought the book and a considerable number passed a good examination in the parts gone over. The subject is out of my province and should be in the hands of a legally educated instructor.

With a small number of students in the department of "Science and Literature" who have attended my lectures I have done a good deal of collateral reading in History and Political Economy, accompanied on their part by a considerable amount of writing. The theses of two graduates in this department, that of Mr. Prentiss, on the condition and resources of the Empire of Austria, and that of Mr. Arnott on Switzerland are herewith presented.

The Elementary exercises in Rhetoric and Composition which I have heretofore given to the first year's class, were this year omitted to make room for exercises in the department of Logic and Philosophy. I cannot but express my regret that more time cannot be found for all the classes for study and writing in connection with the exercises in my department, and that efficient assistance cannot be afforded me in the laborious work of examining written work.

Respectfully presented,

W. P. ATKINSON,

Professor of English and History.

DEPARTMENT OF MODERN LANGUAGES.

President Runkle:—

DEAR SIR, Permit me to submit to you the following report of the department of Modern Languages, with especial reference to its operation during the past year.

I. FRENCH REQUIREMENT FOR ADMISSION.

This is one of the most important matters relating to the department, and has occupied much of the attention and time of the same. It is now three years that French has been among the requirements for admission. During the past two years the amount required has been the same, viz., "French Grammar through Regular and Irregular verbs, and twenty-five pages of easy reading," *i. e.*, the more prominent forms and laws of the language with some practice in reading. The first year (1873) French was required for admission the amount was less, viz., "The first nineteen lessons of Otto's grammar," *i. e.*, the elements of the language as far as regular verbs. The following table gives the results of these three examinations.

1873.	1874.	1875.	
70	41	71	No. taking French in First Year.
53	49	53	Average per ct. at Entrance Examination.
15	5	3	No. admitted without French.
49	26	51	No. admitted without conditions.
81	66	61	Average per ct.
21	15	20	No. admitted with conditions.
10	19	32	Average per ct.

From this it appears, 1st, that the number of those without French has decreased each year; 2d, that notwithstanding the increase in the amount required, the average of the whole class at the examination in 1875 was not lower than in 1873; 3d, that the average of the lowest portion of the class, who had to be conditioned, has been increasing each year; 4th, that the number of those admitted without conditions has slightly increased, while that of those admitted with conditions has slightly decreased.

The experiment therefore of requiring a certain amount of French for admission, that is of having so much of what was previously done in the school made a part of the preparatory work, seems to have been thus far reasonably successful. Still there is very great room for improvement in the quality of the work. There are too many cases now where cramming is evident, and too few where the ground has been well and systematically gone over and thoroughly digested. With the view of facilitating the preparation in French and improving the character of the same, we would offer a few suggestions to be printed in the Annual Catalogue in respect to the manner of treating the French at this stage of its study, thinking that they may be of assistance to instructors and private students.

The amount of French at present required for admission, if well done, would be equal to at least two thirds of a year's work at the Institute, so that certainly there is a prospect of the time when French may be discontinued at the end of the first year, and a full two years' course in the language be regarded as completed. After such a course of practice and training it is probable that students would be able to read easy French at sight and have sufficient strength to solve with accuracy such difficulties as might arise. For the sake of giving a better idea of how a class now stands at the end of the first year, we subjoin the French examination paper at the Annual of the last First Year, the average of the class of thirty-nine students on the same being 56 per cent.

In regard to the *French requirement for the future*, it seems to us desirable to increase somewhat the amount of reading matter, so as to afford a larger field for the observation and study of the grammatical principles. We would therefore, leaving the amount of Grammar as it is, propose sixty pages of easy French instead of twenty-five as at present, and indicate this by "the first two books of Voltaire's 'Charles XII.' (*i. e.*, about sixty pages) or the equivalent of the same."

In the report of this department for last year it was stated that much inconvenience and loss attended the union in one class of students so unequally advanced as were those in the First Year's class of the year before in French. It was suggested also that an *Elementary Class* consisting of those behindhand be formed, to recite by themselves and oftener than the rest. This plan has been carried out the past year and has worked to the great advantage of both parts of the class. This class (consisting of twelve students) had four exercises a week, three being outside of school hours, it being impossible to find time otherwise that would not conflict with regular school duties. At the Semi-Annual this class was merged with the regular one. A like class (consisting of thirteen students) has been formed for the present year. Poor preparation, which makes such a class necessary, is perhaps at first a necessary consequence of a new requirement for admission. But it should be dispensed with as soon as possible by requiring the full amount of candidates before they are allowed to enter. It would certainly seem that after this students who have no French, though prepared in other subjects, should be required to make up by means of private instruction before being admitted.

It is too late now to go back and inquire whether it would not have been more advisable to require *Latin instead of French for admission.* Out of sixty-five students in the class just entered, forty-five report that they have studied Latin and twenty-two that they have not; fifty-one were from schools where Latin was a branch of study and sixty-three from schools where French was. It seems hardly consistent with this to suppose

that a Latin requirement would have been more easily obtained than a French one. Moreover, although it cannot be doubted that the student having a knowledge of Latin to start with would advance much more rapidly on that account in his French, still it is hardly probable that he would get so far at the end of a year as if he had started with a corresponding amount of French. It seems therefore fair to conclude that the requirement of French for admission saves time for other work in the school without being one harder to fulfil than Latin would be.

Of course we do not mean to imply by this that Latin would be of no value to the student at the Institute. On the contrary, it would be of very great value to him, in view of the general culture afforded by its study on the one hand, and its practical bearing upon the various departments of science on the other. It becomes therefore an important subject for consideration whether, in addition to the French, a certain amount of Latin may not sooner or later be required for admission.

II. WORK OF THE PAST YEAR.

This has been conducted nearly in accordance with the revised scheme of studies arranged year before last, that is a two years' course in each of the studies, French and German. The following indicates the disposition of this time:—

French.	Before entrance.	*German*	II Year (2d half).
	I Year.		III "
	II " (1st half)		IV " (1st half).

The number of hours in each of these courses is one hundred and eighty, which however includes the time occupied by Intermediate, Semi-Annual and Annual examinations. Three hours a week have been used for both courses, this number, it is believed, producing the best results. This amount of time is certainly not large for the French. For the German it is decidedly small, when the difficulties of the language are considered, and the amount of practice necessary to obtain any readiness in reading. If the French requires two years, two and a

half years are certainly not too much for the German, if the student is to advance as far in the same.

During the past year the First Year's class has had French; Second and Third Years' classes German. The Fourth Year's class had German the first half of the year. The Second Year commenced German, contrary to the above scheme, at the beginning of the year as heretofore, instead of waiting until the French was finished, it being the intention to have the French finished the first half of the fourth year in the time assigned to the German.. It was felt that, if the German were commenced later, students would not be able to use it in their professional work in the school. It seems to be however undesirable to intermit the French for two years and then resume it for half a year, and better to finish it at once, even if the time for commencing the German should have to be postponed.

Regular dictation exercises have accompanied the recitations, so also regular exercises on the forms and principles of the language. The First Year had read at the Annual two hundred and twenty-five pages, from Otto's French Reader, Mérimée ("Colomba"), and Lacombe ("Petite histoire du peuple français"). The Second year read during the year extracts from Whitney's German Reader, and from Andersen's "Märchen." The Third Year had read at the Annual (*i. e.*, during two years) two hundred and four pages, from Whitney's Reader, Putlitz ("Badekuren"), Zschokke (Wirtshaus zu Cransac"), and Heyse ("La Rabbiata"). The Fourth Year read during the first term portions of the "Goetz von Berlichingen" of Goethe, and of the "Lügen" of Benedix. The average of the Third Year class, of forty-four students, at the Annual on the annexed paper in German was 66 per ct.

The above are the regular courses in French and German for all the students. The "Science and Literature" students of the Third Year had an advanced course in French, in which the "Atala" of Chateaubriand and two plays of Molière were read.

The "Science and Literature" students of the Fourth Year read during the second half from Goethe's "Goetz von Ber-

lichingen," and had also a course in the Science of Language, Whitney's "Language and the Study of Language" being used as a text book.

In the Second year there has been an optional class in French reading, numbering twenty-eight students the first term and twenty-one the second, there being two exercises a week with no time for preparation. Most of About's "L'homme à l'oreille cassée" was read the first term, and portions of "Visites au Jardin d'Acclimatation" by Barr, the second term. The object of these optional readings in French was to remove the objections attending the intermission of the French for two years.

There has been also during the year an optional elementary class in Spanish, composed of students of the Third and Fourth Years, with two exercises a week, no outside work being required. This class numbered ten the first term, and seven the second. For the present year an opportunity will be given to students of the same years to take Italian. In future we would suggest that this class be confined to half of the year, and an hour's preparation be required for each one of the two weekly exercises.

The number of exercises a week in all the studies of this department has been thirty-one the first term, and thirty-two the second.

III. TECHNICAL READING.

Strictly technical reading is quite out of the question in a class composed of students from several departments, for the practical reason that a student in one department does not need the technical words of another. Moreover, the instructor could not be expected to have the proper knowledge of the technicalities in various departments in French and German, any more than in English. On the other hand a student has a special advantage in beginning such reading under the guidance of a Professor in his own department, and with the illustrations at hand which a laboratory affords. This is more especially the

case with the German, where a brief introductory course, for learning technical words and the general style of technical reading is quite necessary, even though a student be well advanced in general reading. Such strictly technical reading has not been attempted in the regular classes. It has however to some extent been carried on by some of the students under the direction of the Professors in the departments concerned.

But if strictly technical reading is not practicable in the regular courses, it is proper to inquire whether scientific reading of a general nature would not be more profitable than something in general literature, as having more or less bearing upon the professional work of the students. This kind of reading has been tried to a limited extent the past year in both French and German, and with such success apparently as to warrant replacing the general reading in a great measure by the same. Perhaps, aside from the practical difficulty of obtaining the proper material for such reading, the only objection to having the entire reading of the student of this nature, is the danger that there would not be variety enough for him to observe the uses and styles of the language as they appear in the various kinds of literature.

IV. MODE OF STUDYING THE MODERN LANGUAGES.

The views of the department on this point remain the same as stated in the last report, only strengthened and confirmed by experience. A thorough grammatical training seems to us essential, if one would understand a language. Without such training and study he cannot expect accuracy and strength in the interpretation of the same. Studying a language indeed, and studying its grammar, must go hand in hand, if the term grammar be taken in its proper sense. The study of Grammar, it is true, has from abuse come to convey to the mind of the student the idea of cramming the memory with certain dogmatic and technical statements not connected with a living organism; while he is further discouraged by having put before

him at the same time what, though of the highest value in its place, belongs to the department of logic not language. But let him consider that grammar is the methodical embodiment of the facts and laws of a language and that, when by actual observation of, and practice on the language itself he is getting possession of its laws and facts, he is studying its grammar. He will then find that he is growing in knowledge of the language in proportion as he is mastering these facts and laws, and that his study has the attraction of the study of any science. The material of a language, consisting in its words, is also essential, but no more so than the principles which teach one how these are used. Our aim has accordingly been to accompany the exercises with methodical statements of the principles as they are indicated by the text. Of course there is danger of going too far in this direction, to the sacrifice of the material and the practice. But if a mistake were made in either direction, it seems to us that it would be safer to make it in the direction of little practice and the acquisition of few words, than in that of an inadequate knowledge of the structure and laws of the language.

Very Respectfully,

Dec. 17, 1875. CHARLES P. OTIS.

[EXAMINATION PAPER IN FRENCH OF THE FIRST YEAR AT THE ANNUAL.]

Translate. — I. On appelle *colons* à cette époque, des hommes qui cultivent la terre d'un propriétaire moyennant une redevance fixe qui s'élève au quart ou à la moitié des fruits. Les colons sont, comme on voit, des espèces de métayers, mais des métayers perpétuels. Le maitre ne peut pas les chasser, et eux, en retour, ne peuvent pas quitter le domaine. On les tient pour personnes libres, mais il faut entendre libre au regard du mâitre et en ce sens qu'ils ne lui doivent que des redevances fixées ; d'ailleurs, ils sont esclaves de la terre à laquelle ils sont attachés, serfs de la glèbe, comme on dira plus tard. S'ils s'enfuyent, le maitre pourra les faire reprendre.

LACOMBE.

II. Dès qu'il eut quitté le tillac, la femme de chambre remonta, et, après avoir fait subir un interrogatoire au matelot, rapporta les renseignements suivants à sa maîtresse : la ballata interrompue par la présence d' Orso

avait été composée à l'occasion de la mort du colonel della Rebbia, père du susdit, assassiné il y avait deux ans. Le matelot ne doutait pas qu' Orso ne revînt en Corse pour *faire la vengeance*, c'était son expression, et affirmait qu' avant peu on verrait de la viande fraîche dans le village de Pietranera. Traduction faite de ce terme national, il résultait que le seigneur Orso se proposait d'assassiner deux ou trois personnes soupçonnées d'avoir assassiné son père, lesquelles, à la vérité, avaient été recherchées en justice pour ce fait, mais s'étaient trouvées blanches comme neige. "Il n'y a pas de justice en Corse, ajoutait le matelot, et je fais plus de cas d'un bon fusil que d'un conseiller à la cour royale. MÉRIMÉE.

III. Orso, répondit Colomba, chacun honore ses morts à sa manière. La *ballata* nous vient de nos aïeux et nous devons la respecter comme un usage antique. Madeleine n'a pas le *don*, et la vieille Fiordispina qui est la meilleure voceratrice du pays, est malade. Il faut bien quelqu'un pour la ballata.

Crois-tu que Charles-Baptiste ne trouvera pas son chemin dans l'autre monde si l'on ne chante de mauvais vers sur sa bière ? Va à la veillée, si tu veux ; j'irai avec toi, si tu crois que je le doive, mais n'improvise pas, cela est inconvenant à ton âge, et . . . je t'en prie, ma soeur. MÉRIMÉE.

IV. Il va poser une première pierre à Corte ; je m'imagine que ce doit être une cérémonie bien imposante, et je regrette fort de n'y pas assister. Un monsieur en habit brodé, bas de soie, écharpe blanche, tenant une truelle . . . . . et un discours ; la cérémonie se terminera par les cris mille fois répétés de *vive le roi !* — Vous allez être bien fat de m'avoir fait remplir les quatre pages, mais je m'ennuie, Monsieur, je vous le répète, et par cette raison je vous permets de m'écrire très-longuement. MÉRIMÉE.

V. (*Passage not translated in class.*) — Pendant le repas, le chef de la loi m'avait fait faire plusieurs questions par Joseph : il voulut savoir pourquoi je voyageais, puisque je n'étais ni marchand, ni médecin. Je répondis que je voyageais pour voir les peuples, et surtout les Grecs qui étaient morts. Cela le fit rire ; il répliqua que, puisque j'étais venu en Turquie,[1] j'aurais dû apprendre le turc. Je trouvai pour lui une meilleure raison à mes voyages, en disant que j'étais un pèlerin[2] de Jérusalem. Il fut pleinement satisfait. La religion est une espèce de langue universelle, entendue de tous les hommes. Ce Turc ne pouvait comprendre que je quittasse ma patrie par un simple motif de curiosité, mais il trouva tout naturel que j'entreprisse un long voyage pour aller prier à un tombeau.[3]

CHATEAUBRIAND.

1. Explain the pronouns *eux*, *laquelle* (V) ; *m'(ennuie)*, *m'(écrire)* (II).

2. What is the tense in "dès qu'il m'eut quitté" ? Is there any rule as to the use of this tense ?

[1] Turkey. [2] Pilgrim. [3] Grave.

3. Explain the form of the past participle in "*ils sont attachés*," "*s'étaient trouvées*," "*m'avoir fait remplir*," giving the rule of agreement in each case.

4. What mode and why in *Orso ne revint* (II), *que je le doive* (III), *que j'entreprisse* (V)?

5. Give the principal parts of *doivent* (I); *subir* (II); *faut* (III); *écrire* (IV); *entreprisse* (V).

6. State when the past participle remains invariable.

7. What verbs can be followed by an infinitive without any preposition?

8. When is the compound of present chiefly used? Of what other tense may it at times take the place?

9. What is the difference of meaning between *aussi* at the head of a sentence and after a verb; between *puis*, *puisque* and *depuis*; between *ailleurs* and *d'ailleurs*?

10. What would be the construction in French of these two sentences: *I believe I am right* and *I believe he is right*?

Translate.—1. The danger in which he finds himself is great. 2. Your tale[1] amused me; tell it to him also. 3. The letter which I have begun to read is badly written. 4. We obtained peace[2] by making sacrifices. 5. The qualities of Alexander were those of a king, his faults those of a soldier. 6. I lent him all the aid[3] I could. 7. It does not seem that you love him. 8. I do not doubt that your Majesty will learn with pleasure that I have discovered a world. 9. I could not prevent him from falling. 10. He was ready to go up to his room when some one knocked at the door.

[1] conte (m); [2] paix (f.); [3] assistance (f.).

FIRST YEAR. MAY, 1875.

[EXAMINATION PAPER IN GERMAN OF THE THIRD YEAR AT THE ANNUAL]

I. Vielleicht wären alle dieſe aufgezählten Urſachen der Dürre und Wärme nicht hinlänglich, ſo beträchtliche Theile der afrikaniſchen Ebenen in ein furchtbares Landmeer zu verwandeln, hätte nicht irgend eine Naturrevolution, z. B. der einbrechende Ocean, einſt dieſe flache Gegend ihrer Pflanzendecke und der nährenden Dammerde beraubt. Wann dieſe Erſcheinung ſich zutrug, welche Kraft den Einbruch beſtimmte, iſt tief in das Dunkel der Vorzeit gehüllt. Humboldt.

II. Folgt auf die brennende Hitze des Tages die Kühlung der, hier immer gleich langen Nacht, ſo können Rinder und Pferde ſelbſt dann nicht ſich der Ruhe erfreuen. Ungeheure Fledermäuſe ſaugen ihnen, während des Schlafes, vampyrartig das Blut aus; oder hängen ſich an dem Rücken feſt wo ſie eiternde Wunden erregen, in welche Mosquitoes, Hippoboſcen und eine Schaar ſtechender Inſecten ſich anſiedeln. So führen die Thiere ein ſchmerzenvolles Leben, wenn von der Gluth der Sonne das Waſſer auf dem Erdboden verſchwindet. Humboldt.

III. Mit dem Eintritt in die Südbonauländer erfolgten Angriffe der hier wohnenden Bulgaren; ſie tödteten manchen Pilger mit ihren Pfeilen, ſpießten einzelne Gefangene und

wurden erſt geſchreckt, als Kaiſer Friedrich ſtreng das Wiedervergeltungsrecht ausüben, und eine ihrer Städte Brunduſium zerſtören ließ. Auf die Griechen fiel wegen dieſer Feindſeligkeiten zunächſt kein Verdacht, weil man ſehr gut wußte, daß die eingewanderten Stämme ihnen nicht gehorchten; als aber Gefangene bekannten, daß man die Bulgaren allerdings von Konſtantinople aus angereizt habe, entſtand Argwohn, welcher noch höher ſtieg, da die Fürſten von Servien und Racźna dem Kaiſer bei Nizza perſönlich aufwarteten, für Lebensmittel ſorgten und zugleich ihre treuen Dienſte gegen die ſtets ränkevollen Griechen anbotent

Raumer.

IV. (Passage not read before.)

Noch ungefähr eine halbe Stunde fuhren die Reiſenden die glatte, ebene Schauſſee[1] entlang, dann bogen ſie ſeitwärts ab in den dunkeln Wald, durch den ein gutgehaltener Fuhrweg lief. Die Sonne zeigte ſich bereits in voller Pracht am Himmel und blickte verwundert lächelnd auf die Erde, die ohne Vorwiſſen ihrer hohen, leuchtenden Protectorin ſich über Nacht einen prächtigen Brillantſchmuck angeſchaft hatte. Nach Mitternacht war ein ſtarkes Gewitter über die Gegend gezogen; es hatte viel geregnet, noch hingen ſchwere Tropfen an Bäumen und Geſträuchern und fielen rauſchend auf das Wagenverdeck, wenn der Poſtillon mit der Peitſche einen niederhängenden Aſt berührte.

Marlitt.

[1] Highway.

1. Prin. Pts. of zutrug; (I); ſaugen, verſchwindet; (II); ließ, fiel, anboten (III).

2. Give in full the Fut. Act. and Pass. of verwandeln (I). How would wird gehüllt differ from iſt gehüllt (I).

3. As what part of speech may the infinitive be used, and how is it then treated. What is put before it, when it is used to express a purpose. After what verbs is zu not used with the infinitive.

4. Explain the subjunctives hätte (I), angereizt habe (III); explain the tense of the latter. State the main divisions of the subjunctive.

5. Construction of Theile, Gegend, Pflanzendecke (I); gleich, Nacht, Ruhe (II); Wiedervergeltungsrecht, ihneu, (von Konſtantinopel) aus (III).

6. Analyze the following words, hinlänglich, afrikaniſch, furchtbar, Vorzeit (I); ſchmerzenvoll (II); Süddonauländer, Wiedervergeltungsrecht, Feindſeligkeiten (III); stating which are compound and which derived, and the force of the suffixes.

7. What *endings* of nouns denote the feminine gender. Nouns of what *signification* are feminine. Illustrate from the texts.

8. Give the corresponding English for zählen, tragen, Kraft, Zeit, hüllen (I); Rücken, Thier (II); treten, ſtören, ließ, wiſſen, horchen (III).

6. Distinguish between wann, wenn; welcher, der; aber, ſondern; erſt, zuerſt; Staat Stadt; kopf, Haupt.

V. 1. John's books are still lying on the sofa in the drawing-room, and he has gone out riding. 2. I am afraid that our expected guests will stay away to-day, because it is bad weather. 3. I think that I have read too long, for my eyes pain me very much. 4. Come to our house to-morrow, if

you wish to see my father; but you must be there punctually, for he goes out at eight o'clock. 5. My friend dines with me on Sunday, which habit he has had for years. 6. He said that they were in the same town the whole summer through, without seeing each other a single time. 7. I have had to act thus, because my brother wished it; in this matter I am determined not to act against his wishes. 8. Our whole family was yesterday evening at a concert at Mrs. S.'s, where there was much dancing. 9. Can you remember how his summer house by the river side looked? 10. Without heeding [1] my express [2] commands, he has run away, in order to amuse himself somewhere,[3] or to attend to [4] his own affairs.

[1] achten auf. [2] ausdrücklich. [3] irgendwo. [4] besorgen.

DEPARTMENT OF MILITARY SCIENCE AND TACTICS.

President J. D. Runkle: —

SIR, In this my report for 1875, the centennial year of the first battles of the Revolution, I may be pardoned for adverting to the importance of causing a certain degree of military instruction to be given, side by side with instruction in the arts of peace. The fruits of the latter can only be fully assured to us, by ability to defend them against aggression. I can not do better than quote the words of Washington: —

(From Inaugural Speech, April 30th, 1789.)

"Among the many interesting objects which will engage your attention, that of providing for the common defense will merit particular regard. To be prepared for war is one of the most effectual means of preserving peace.

"A free people ought not only to be aroused, but disciplined; to which end a uniform and well digested plan is requisite;" * *

(From Speech to both Houses of Congress, Dec. 3d, 1793.)

* * * * * * * * * * * *

"I cannot recommend to your notice measures for the fulfilment of *our* duties to the rest of the world, without again pressing upon you the necessity of placing ourselves in a condition of complete defense and of exacting from *them* the fulfilment of *their* duties towards *us*. The United States ought not to indulge a persuasion that, contrary to the order of human events, they will forever keep at a distance

those painful appeals to arms, with which the history of every other nation abounds. There is a rank due to the United States among nations, which will be withheld, if not absolutely lost, by the reputation of weakness. If we desire to avoid insult, we must be able to repel it. If we desire to secure peace, one of the most powerful instruments of our rising prosperity, it must be known that we are at all times ready for war." * * * * * * * *

Until the entire nature of the human race has become changed, it will be necessary to provide for defence against armed aggression by foreign nations, and also against internal attempts to subvert our liberties. On political and economical grounds it is undesirable to maintain a large standing army. It is then to the people, *en-masse*, that we must trust for defence. To do this effectively, experience has shown that they must be provided with capable instructors and leaders, officers.

These would naturally be selected from the most intelligent and educated citizens, from the graduates of our institutions of higher learning. The wisdom of legislation which requires military instruction to be given in institutions receiving a certain public bounty is obvious.

Permit me to quote from a letter written by President Andrew D. White of Cornell University.

"The law, as it now stands, enables at least one collegiate institution in each State to send out every year, a body of men with a good substantial knowledge of military matters, to aid in keeping up citizen soldiery, and to be of use in various communities, in case of emergency. Of course, the highest military education in the country must be given at West Point. But the instruction given to the country under the slight expense caused by the existing law, is, it seems to me, a matter which any statesman should take care of.

"It has always seemed to me that the control of citizen military organizations should be kept, as far as possible, in the hands of the more thoughtful and better educated classes. I dread to see the day arrive when, with the civil commotions sure to arise in a Republic as wide in extent, and as thickly settled as ours is to be, the thoughtful men and the educated men will be shrinking in corners for want of

the simple elements of military knowledge, and military organizations for emergencies will be entrusted to men of little or no character and standing. Take the Rebellion — we had, then, an opportunity to note the advantage gained for the Confederacy by the fact that so many of their better educated men had some military training at their schools and colleges.

"As a Professor at the University of Michigan, I saw the other thing. I saw at that institution our very best young men — and the best were the very first to enlist — go forth under the charge of a drunken blackguard, taken out of a lager beer saloon, his only title to command being that, in all that community, he was the only one who had any military knowledge, he having been a non-commisioned officer during the Mexican war. The result, I need hardly tell you, was disastrous. This company of noble young men melted away, and the captain was one of the few who came back.

"I have thought much upon this, and it seems to me that the clause in the Bill of 1862, providing for military instruction in the various State colleges, and the supplementary legislation since, allowing the detail of the army officers to conduct this education, showed real statesmanship.

"In view of emergencies which are sure to arise, sooner or later, in a Government like ours, may I not ask you to give this matter your careful consideration, and to see, if possible, that a provision in all respects so beneficent, be not destroyed."

Unfortunately, there is a tendency to construe this law and to meet its requirements in a manner so antagonistic to its spirit, that the amount of good derived therefrom is reduced, most frequently, to a minimum.

In all wars, the loss of life by disease far exceeds that resulting from actual combat. It is therefore essential that, first of all, instruction be given how properly to care for the health of troops when subjected to abnormal fatigues and exposure. *This should commend itself simply on the ground of humanity, as it is for the purpose of preventing suffering and loss of life.* War, at best, is horrible. It is inevitable in the affairs of all nations. Let us deprive it of its stings and horrors as far as human foresight, based upon experience, will admit. In our

eagerness to acquire material prosperity, let us not close our eyes to the dangers and contingencies of the future, however far removed they may seem at present.

Besides the instruction as to the care of the health of troops, it is necessary to instruct in the mode of organizing, disciplining and drilling troops, not alone in the actual details, which may be changed from time to time, but also in the general principles involved and their *rationale.*

The Military Instruction during 1874-5.

The instruction during the year ending May, 1875, was satisfactory, when one considers the many drawbacks arising from limited time and a lack of hearty support to the work of the department. This was made apparent by the written examinations and closing drill. The students were, apparently, very much interested. The officers performed their duties in an efficient manner. Commissions were given, at the closing exercise to the following:

Staff Officers ranking as First Lieutenants.

Adjutant: G. F. Swain.
Quartermaster: E. H. Gowing.
Signal and Ordnance Officer: J. Kirk.
Captains: F. E. Peabody, C. H. Morton, W. Jenney, A. G. Everett.
First Lieutenants: H. J. Monroe, W. M. Peters, C. H. Fisher, I. M. Story, F. P. Spalding.
Second Lieutenants: W. A. Frost, C. F. Lawton, E. G Faber.

The warrants of the non-commissioned officers were presented at the same time. No commission or warrant will hereafter be given to any student who has not shown a capacity for performing efficiently the duties of the office conferred, or one of higher grade, in actual service.

Voluntary Encampment.

On May 31st, 1875, twenty (20) students accompanied me for a week, in a voluntary encampment near Lexington, Mass.,

on grounds belonging to the Hon. John Cummings. The tents and camp equipage were loaned to us by the courtesy of the Adjutant General of the State. The camp was laid out and the tents were pitched by the students. They here put into practice some of the makeshifts of camp life, which enable soldiers to make themselves comfortable under unfavorable circumstances. The regular duties of the camp were performed by the students early in the forenoon and late in the afternoon, thus giving them the greater portion of the available day for their own recreations. Voluntary exercises of day and night signalling, and target shooting, were given. Parties of two or three were detailed to cook certain articles of food in the same manner and with the same facilities that soldiers in the field would be apt to have. All these experiments were successful. The relaxation afforded by this encampment, after the severe mental tax imposed by the annual examination, greatly benefited all. This was evidenced, if in no other way, by the excellent appetites and increased weight of every student who participated in the encampment. Our thanks are due for many courtesies extended by inhabitants of Lexington. The conduct of our students was, throughout, unexceptionable. The fears that were expressed, that discredit might be brought upon the Institute by the reckless conduct which but too frequently characterizes encampments, were without foundation. On Sunday, all attended Divine Service except those who were required to take charge of the camp. It is my desire to repeat this at the close of the next year. May not this be advantageously extended to all classes, accompanied by some of the Instructors, and be, in so far, an extension of the general system of the school in giving technical instruction? Much useful instruction might thus be given in the laboratories of nature. The civil engineering students might have exercises in various kinds of surveying. A week might be advantageously spent in geological work. For this purpose the locality of the encampment might be changed from year to year. Botanical instruction

might be imparted in the woods and fields. With all this, opportunities would be secured for out of door sports; relaxation, so necessary after the severe strain imposed by the annual examinations, would be given. Useful instruction and experience would be gained in the makeshifts of camp life and in the preparation of food in the field.

The Military Instruction during 1875-6.

As so much of the school year of 1875-6 has elapsed at the time of making this report I will extend it sufficiently to cover the time up to date of writing.

The principal objections which presented themselves to the Faculty and some of the students against the military instruction as it was, were, that after entering the second year, it interfered with the strictly professional work of the students; on my own part, that I could not give a sufficient amount of the theoretical instruction in the duties of officers and yet have the *battalion* as well drilled as it should be. With all this in view, desirous alike of seeing the military instruction established on a basis which would be unobjectionable, of receiving the support of the Faculty, and of being able to attain better results, I proposed the following plan, at the opening of the school year, based upon the understanding that the Corporation and Faculty had, *conjointly*, allotted the *time* of two hours per week for two years, to military instruction: —

1st. (a.) That the drill should be obligatory only during the first year, but for *three* hours, instead of *two*, per week.

(b.) Permit such second year students, as volunteer, to drill. I should be likely to get only such men as would be competent and desirous of performing the duties of officers.

(c.) Have the battalion organized as two companies instead of four. Allow the officers (second-year students) a small deduction of tuition fee for performing their duties. Have these appointments subject to the control of the Faculty, in order that no student be permitted to occupy an office, the duties of which

would prevent his attending properly to his studies. By this system I felt confident that the drill and discipline of the battalion, at the end of the year, would be better than in previous years.

2d. Require second-year students to attend exercises of one hour per week, either lecture or recitation, in subjects pertaining to the duties of officers; about one-third of these exercises would be lectures, two-thirds recitations. The lectures would require, on an average, one-half hour of not very hard reading in preparation. Objections having been made that by this plan, more time would be given than before, on account of time required for preparation, allowance was made for this, and the number of exercises for the second year was reduced to twenty-four (24). The results have been eminently satisfactory, both Faculty and Students apparently acquiescing in this arrangement, as being the best solution which could be arrived at, based upon the premise that military instruction shall be given and received in good faith. It is desirable that this shall be recognized as its permanent *minimum* status.

The following is the roster of acting commissioned officers at the present date.

Staff Officers ranking as First Lieutenants.

First Lieutenant and Adjutant: E. F. Williams.
First Lieutenant and Quartermaster: J. Kirk.
First Lieutenant, Signal and Ordnance Officer.
Captains: I. Rich, D. Pierce.
First Lieutenants: L. O. Towne, E. S. Draper.
Second Lieutenants: E. C. Miller, A. T. Lincoln.

The Gymnasium and Physical Culture.

The outfit of the Gymnasium of the Institute is tolerably complete, and requires but a few pieces of apparatus to make it as complete as any in this vicinity. A large proportion of the students have availed themselves of it. But now that we have the Gymnasium, one step further seems desirable, *i. e.*, the adoption of a system of *obligatory* gymnastic exercises. The

students who most need physical exercise are the very ones who least take it, either in the gymnasium or elsewhere. The mind cannot be used advantageously unless the body is in good condition. The Faculty of the Institute prescribe certain studies and methods of study, which, in their judgment, will ensure the greatest mental vigor and greatest amount of mental acquirements. It, therefore, seems a vital omission not to also prescribe such physical exercise as will place the body, and consequently the mind, in the best possible condition to sustain the burden which is put upon it. As the mental instruction given at the Institute is but the foundation upon which its students are to build after graduation, it would seem but a natural and necessary complement of the work of the school, so to exercise and develop their bodies, as to send them forth physically, as well as mentally, strong. The mental strength which may be acquired at the cost of the physical can avail but little, wasting itself prematurely in its feverish efforts to realize itself. Engineers, as a rule, do not have the opportunities to distinguish themselves by great works until after they have practised their professions for years, and shown their capacity by successfully performing many works of minor importance and magnitude. Their calling demands an incessant exercise both of body and mind. How important, therefore, that they should be duly strengthened for their work, by such preparation of the body as the experience of years has shown to be feasible and profitable. It may be said that the time of the students is so much taken up as to make it impossible to assign any time for a regular physical exercise. It will be found more profitable to *make* this time. Require every student to participate daily in an exercise of from fifteen to twenty minutes, and I have but little doubt that fewer complaints will be made of excessive burdens being imposed in their studies. These exercises should be of such a nature as to improve the respiration and to impart a general tone of health in the entire body, developing in harmony all parts and functions of the body. They may be comparatively light in their nature,

and should be given under the direction and supervision of a physician, in order that no student, however weak, may be injured by any inordinate or misdirected exercises. The introduction of obligatory physical culture into the curriculum of the Institute can hardly be considered in the light of an uncertain experiment. A system of such culture has been in active operation at Amherst College for nearly fifteen years. In this connection I would quote the following extracts from a report on that subject, by Dr. Nathan Allen: —

"In President Stearns' Report to the Trustees for 1859, the health of the students again constituted a prominent topic. He says, 'time and experience have convinced me of an imperious demand, in the circumstances of an academic life, for immediate and efficient action on this subject: many of our students come from farms, mechanic shops, and other active occupations, to the hard study and sedentary habits of college. Physical exercise is neglected, the laws of health are violated, the protests and exhortations of instructors and other friends are unheeded. The once active student soon becomes physically indolent, his mental powers become dulled, his movements and appearance indicate physical deterioration; he makes occasionally spasmodic efforts to regain his former elasticity by exercise, but by finding discomfort more than advantage from it, he eschews exertion and becomes more inert than ever.

"'By the time the Junior year is reached, many students have broken down their health, and every year some lives are sacrificed. Physical training is not the only means of preventing this result, but it is among the most prominent of them. If it could be regularly conducted, — if a moderate amount of physical exercise could be secured as a general thing to every student daily, I have a deep conviction, founded on close observation and experience, that not only would lives and health be preserved, but animation and cheerfulness, and a higher order of efficient study and intellectual life would be secured. It will be for the consideration of this Board, whether, for the encouragement of this sort of exercise, the time has not come, when efficient measures should be taken for the erection of a Gymnasium, and the procuring of its proper appointments. It is a settled conviction in my own mind, that only by a certain amount of regular exercise

together with attention to other laws of health, can that listlessness and dullness and inefficiency which is so hostile to good scholarship and so common among students, be overcome.'" * * * * *

The following are mentioned as some of the results of the system of required physical exercise which was adopted a short time after the publication of the above mentioned report.

"1st. There has been a decided improvement in the very countenances and general physique of the students. Instead of the pale, sickly and sallow complexion once very commonly seen, with an occasional lean, care-worn and haggard look, we now witness very generally, fresh, ruddy and healthy countenances, indicative of a higher degree of vitality, and thus the vital currents, enriched by nutrition and oxygen, have a free and equal circulation throughout the whole system. * * * * * * * * * * *

"2d. In the use of the limbs and the body,—in the physical movements and conduct of students generally, there has been, we think, decided improvement. * * * * * * * * *

"5th. A comparison of the present health of students with what it was ten or fifteen years ago, shows a surprising improvement. It is rare now for any student to break down suddenly in his health, or to be compelled to leave college on this account. In 1855-6-7 and 8 such cases were common, as may be seen by referring to the statements of President Stearns in the opening of this paper; and the truth of the statements is moreover confirmed by others personally conversant here for twenty or thirty years. As no record was formerly kept of the amount of sickness from year to year, or of the number of students leaving college on account of illness, no exact comparison on these points in figures can be instituted. But the experience and observation of those who have been on the ground a long time must bear decided testimony to a greatly improved state of health among the students over that of former times; and as for those who once were members of the Institution, and return here on public occasions, they cannot fail to see a great improvement in this respect. * * * * * * * * * * *

"7th. But the most marked evidence of improved health is found in the diminished sickness of every class each year after entering college.

In a table giving the amount of sickness arranged by classes, it seems there has been for these eight years on an average *more than three times* as much sickness in the *Freshman* Class as in the *Senior* Class. It may be said that the students upon first entering college do not know so well how to take care of themselves as they do in the third and fourth years; or that some students who come here feeble and sickly, leave the Institution early, so that the vigorous and more healthy alone remain. This may account in part for the change, but only for a small part of it. For some students who now enter college with slender constitutions encounter considerable sickness the first year, but afterwards improve in health, and in the third and fourth years are comparatively well. And the number now leaving college during the first and second years, on account of ill-health, is very small. Then again, if we compare the sickness or health of a class all the way through college now, with that of one ten or fifteen years ago, a surprising difference will be found; if the sickness did not then increase or keep up through the whole course, it certainly did not diminlsh so much in the second and third years and almost entirely cease in the fourth, as is the case now. * * * *

"There is still another very important consideration, viz.: has the standard of scholarship in college been raised by means of gymnastics? As the system of marking, or mode of exhibiting this standard was changed a few years since, an exact comparison in figures cannot here be instituted; but it is the decided opinion of the Registrar, (the College Officer who has charge of these statistics,) that there 'has been an elevation of rank within the past few years.' It may be that some individuals in a class formerly reached as high scholarship as any now do; but the *aggregate* scholarship of a whole class, we are confident, is higher now than it once was, and, to say the least, is much easier obtained, with fewer hours of study, and less loss of health and life. * * * * * * * *

"Said President Felton to the writer, shortly before his decease, referring to the gymnastics at Amherst which he had just witnessed: 'Such a system of physical exercises thoroughly understood and applied by the members of Harvard University, would aid me in the matter of discipline in that Institution more than anything else.' We are here authorized to state, that the faculty of Amherst College have found great assistance in government from this source; — that since

the introduction of this department, the cases requiring discipline have been far less numerous, and more easily managed, than formerly."

Having quoted some of the most essential portions of this admirably written report, wherein the opinions of the *governing authorities* of the college have been cited, I submit, likewise, a letter written by the *students*, viz;—

"TESTIMONY IN FAVOR OF THE GYMNASIUM.

"AMHERST COLLEGE, June 14th, 1865.

"The class of 1865, having completed its studies in Amherst College, desires to express its high appreciation of the physical culture which it has received under the direction of Prof. Hitchcock. As this class is the first one in College which has enjoyed through its whole course this physical training, some expression of opinion seems quite proper. There have been ninety-two different students connected with the class, fifty-five of which now graduate; eight have died,—two with consumption, and six in the army from wounds or disease. There is no one of the graduating class but could pass a complete examination for life insurance or admission into the United States Army. From a thorough trial of four years' course of training, we can fairly judge of the system here adopted. Our exercises have been conducted in a well-furnished gymnasium, and always under the direction of the Professor in this department. We have found the required attendance — a part of the system — not at all objectionable, and, what at first in the exercise was a little embarrassing or unpleasant, soon became a positive pleasure. The simultaneous participation of many persons in the same exercises has contributed a lively zest to them, when otherwise they would have proved dull and uninteresting. These exercises have been so varied in character as to be adapted both to the strongest and the weakest student, conducing alike to health, strength and grace of action. The half-hour required for exercise has proved the golden mean between length and brevity of time for this purpose, and has never been considered lost by us, as our health at the close of our college course testifies to the inestimable value of this training. We are confident, if this matter of exercise had been left a voluntary thing, many of our class, who are now strong and healthy, would have yielded to the diseases incident to student life.

while others, who were weak and slender boys on entering college, are now strong and vigorous men. Cases of protracted illness have been almost unknown among us, and large numbers in the class have not been detained by illness from a single college duty. Believing that a strong body is the best bulwark to a sound mind — that strong muscles and well-developed limbs are powerful aids to the brain, — and being indebted very much for these results in our case to the physical training we have received in Amherst College, — we give this voluntary testimony to the value of the system of gymnastics here adopted."

"E. P. Frost,
M. K. Pasco,
A. H. Howland, } *Committee.*"

Consideration of these statements and facts, as also that of others which the already too great length of this report prevents me from mentioning, have convinced me of the great importance of adopting similar measures at the Institute of Technology. Whilst the suggestions herein embodied are foreign to my province as military instructor, I felt impelled to make them from my interest in the welfare of the Institute and a deep seated conviction that the adoption of a system of obligatory physical exercises would eventually enhance its efficiency and reputation, inasmuch as its graduates would leave it with unimpaired, nay *improved* health, instead of being physically weakened by their labors. They would be more certain to live long enough to reflect credit upon their Alma-Mater.

Respectfully submitted,
E. L. ZALINSKI,
1st Lieut., 5th U. S. Art'y.

REPORT UPON THE LOWELL COURSE OF PRACTICAL DESIGN, FOR 1874–75.

President J. D. Runkle:—

SIR:—The success of this Department (Practical Design for textile fabrics) has been most flattering during the three years of its existence, terminating in May 1875.

It is provided with all the requisite facilities and novelties necessary for the study of Practical Design. Samples of carpets, oil cloths, silks, laces, cachemeres, shawls, paper hangings, percales, muslins, prints, cretonnes, etc., are received every year, anticipating current styles. Under these favorable auspices, fifteen students have now graduated, eleven of whom have secured situations in different manufactories in the New England States. We have had during the year two public exhibitions of pupils' work, one at Horticultural Hall, Boston, and the other at Lowell, which proved highly gratifying to visitors, and the manufacturers especially.

The advanced pupils have the privilege during each season of showing their designs to manufacturers and frequently succeed in disposing of their patterns. The amount received by students for their designs, in oil cloth and prints, has reached about three hundred dollars. The following is a list of the graduates from this Department, who have received the certificate of proficiency.

James L. Folsom . .	Hartford Carpet Mill., Thomsonville, Ct.
Henry Morse . . .	Carpet Mill, Maine.

Alex. Johnston . . .	Pacific Mills.
Ernest Pierce . . .	" "
Everett Anthes . . .	Manchester Print Works.
Miss Mary Jefferson . .	" " "
Miss Elizabeth Mendum .	" " "
Carroll Faunce . . .	Hamilton Woolen Co.
Charles Cowdery . .	Oriental Print Works.
Howard Hinckley . .	Merrimac Co.
Miss Mary Ricker . .	Hamilton Manufacturing Co.
Miss Annie Barnard . .	No situation.
Miss Kate Simonds . .	" "
Henry Mabille . . .	" "
Edward Williams . .	Lithographer.

Respectfully submitted,

CHARLES KASTNER,

Director.

REPORT ON THE FIRST YEAR'S COURSE IN FREE HAND DRAWING.

President Runkle: —

DEAR SIR: — In the courses of Civil, Mechanical, and Mining Engineering, and Architecture, as given at the Institute, one of the most important branches and one which requires a large proportion of time for its thorough acquisition, is Mechanical Drawing; and a proficiency in this branch is one of the most useful and necessary things in after professional life. But in order to become an expert or even a fair draughtsman, a firmness of hand and knowledge of form are necessary, that cannot be obtained by mere mechanical work and can only be acquired by a course of practice in free-hand drawing.

The value of free-hand drawing is very apt to be underrated in a scientific school, but it is absolutely the making of good draughtsmen. And those who are the most proficient in it will always succeed well in their mechanical work. Its value is seen in the execution of all shaded drawings, in good lettering, in the neatness and taste shown in the work, and indeed in every line that depends upon anything beyond a straight edge and pair of dividers.

The subject as given at the Institute is not laid out with any artistic end in view, but it is merely intended to give in the time allotted to it, that portion of elementary free-hand drawing which will be of the greatest use in mechanical work. The first lessons consist in exercises on straight lines, circles, and

simple curves; after which Schubert's plates are taken up, and the remainder of the time spent in drawing from them. These plates consist of lithographic copies of simple machine details. They are all details of frequent use and are taken from the best designs; are correctly and nicely shaded, part by line shading and the rest by simple cross-hatching, and introduce a number of simple forms, so that the student learns from them the application of light and shade to a large variety of surfaces.

The drawings are made upon brown paper, and the crayon point is used in preference to the pencil, as it requires a greater delicacy in the handling and gives a much better effect in a much shorter space of time.

The first term is thus spent in learning the mere execution of outline and shading; but during the second term, some attention is also paid to making drawings of objects so as to show their three dimensions. The first part of the term is then spent in isometric drawing, that being one of the simplest methods of showing bodies in this manner; and the remainder of the term is devoted to free-hand perspective. In both of these subjects, large plates are made of various geometrical solids and hung up at the end of the drawing-room to be used as copies. The drawings then made by the students are shaded by line-shading, the shadows also being carefully put in. Such parts of the theory as are necessary are given from time to time in short lectures preceding the regular exercises.

It would be of great advantage to many students to have some knowledge of sketching, but with the present limited time devoted to drawing, it is impracticable to take up this branch at all, so that the course, as at present arranged, ends with the subject of perspective. The number of plates drawn by each student varies greatly owing to the difference in the rapidity with which they work. A certain number of plates, however, are required, and the students finish as many more as they can. The total number required amounts, in the year's course, to twenty, and the average of the students complete three or four

more, while a few will do eight or ten more; but these latter usually include the best and poorest workmen in the class, so that the number of plates completed is no criterion as to their excellence.

Examinations are held twice a year. At the Semi-Annual, the projections of some solid are put upon the black-board together with its proportions, and the students are required to make a correct drawing from them, both in outline and in shade. A fixed time is allowed them, so that the rapidity with which they work is thus taken into account in determining their mark. At the Annual examination, similar projections are given them to draw from, but this time they are required to make a correct shaded drawing of the object in perspective. And in addition to this a few questions on the theory of the subject are given.

Free-hand drawing requires patience and perseverance more than anything else for its successful accomplishment. A hard working and not particularly talented student usually excels a more gifted but less patient one. But when a student has a peculiar talent for the subject and unites patience and perseverance with it — and there are usually several such in every class —excellent work is the result. So the standard of any class in Free-hand drawing is very apt to be the same as its standard in other studies. But there are always a few in every class who appear to be entirely without any ability to draw, though many of them try their best and are faithful in their work; but in all such cases due credit is given for their perseverance. As was said before, the regular course does not aim at teaching anything more than the elements of drawing. But there is a good collection of casts at the disposal of the department, and special students and such regular students as are interested in their drawing, and desire to continue it, have special instruction.

Respectfully yours,

FRANK B. MORSE.

REPORT OF THE FIRST YEAR MECHANICAL DRAWING.

President Runkle: —

In compliance with your request I herewith submit the following report of the manner of instruction and the work accomplished in Mechanical Drawing in the First Year's class of 1874–5.

During the first year the students are taught the use of the drafting instruments and such general principles of Mechanical Drawing as are applicable to all the various divisions of the subject created by the different professional courses. To this end therefore, the work of the year has been conducted. Professor Warren's three elementary works, "Drafting Instruments," "Elementary Projection Drawing" and "Elementary Perspective" were used as text books, and from them the system and examples were chiefly taken. "Drafting Instruments" was the first book taken up, from which various examples having the following ends in view, were selected and drawn. Proficiency in the use of the drawing instruments, familiarity with a few important geometrical problems, the manner of laying on ink and color washes with the brush, the conventional representations of wood, iron, stone, and earth, water sections, and a limited amount of lettering. The latter consisted of three title pages, one for each principal division of the year's work. Seven weeks were given to this subject. Projections were next taken up, under the head of which was included the principles of

shades and shadows, isometric drawing, shading and construction drawing from models and copies. In projections proper were given the mode of representing the plan, and end and front elevations of rectilinear and cylindrical figures, when seen both in parallel and oblique projection; also problems covering the most general cases of the intersection of solids, both by planes and by other solids, together with their developments. The subject of shades and shadows was pursued by first finding the shades of objects and then their shadows when the latter fall on the vertical or horizontal planes of projection, or on both; and secondly, by finding the shadows on oblique abutments and the like, by means of auxiliary planes. Examples were drawn in isometric projection which included the manner of representing isometric and non-isometric lines, circles, and curved lines, together with isometric shadows. At this stage, practice was had in shading with India ink, some of the isometric constructions being made with special reference to this. As this was for pictorial effect only, but little time was devoted to it owing to the amount of work to be done on more important subjects. It is very desirable, however, that the students should have more practice in making highly finished drawings of structure designs and inventions. Much more time than is in my power to allow for the purpose could be profitably employed in this manner. The year's work gone over thus far, was next practically applied by making one or two construction drawings, the examples being taken from the book, from notes, and from the model. This completed the course in projections after thirteen weeks had been spent on the subject. During the remaining ten weeks of the term Elementary Perspective was taken up. Between two and three weeks were devoted to the natural method of perspective drawing as founded on projections. This consists of finding by projections where a visual ray from a given point to the eye pierces the perspective plane. It satisfies in the most natural manner the simplest geometrical definition of the perspective of a given point, viz., that it is where a visual ray from that point pierces a picture plane. This method however, when

applied to any but the most simple objects, complicates the drawing to such an extent that it is not a desirable one to use for practical work. Nevertheless it has a certain value, for it gives to the student a knowledge of the principles upon which the artificial or derivative methods are based. The remaining weeks were given to drawing in perspective both simple and complicated examples, by the methods of diagonals and perpendiculars and of vanishing points.

All the work thus described was drawn on uniform sheets of twelve and one half, by eight and one half inches in size, and at the end of the year were bound in neat paste board covers. Besides this course from the text books, at the end of each of the following subjects, additional drawings from notes and models were made on sheets eighteen, by twelve and one half inches in size. Immediately following the elements of drawing as taken from "Drafting Instruments," drawings were made on one of these sheets which served both as a review and as an application of all previously gone over. Following projections proper, a sheet was filled with a few simple applications of the subject to the drawing of patterns for constructions in sheet metal, and the like. A large and complicated line drawing, with its shadow falling on both planes of projection, was constructed from the model as a review of shades and shadows. Two large shaded drawings in perspective completed the year's work in Mechanical Drawing. These review plates, as they were called, were required of all the students as a part of the regular course.

Regular drawing exercises of five hours per week were held in the drawing room, during which time each student received personal instruction whenever it was required. In addition to this, recitations were held once a week in the class room and lectures given on the Theory of Drawing. As far as possible these exercises in theory were kept in advance of the work in the drawing room, in order that the students might progress with their drawing as rapidly as possible.

Seven examinations were held in Theory of Drawing during the year, including those of the Semi-Annual and Annual. At the former, three students were conditioned, and one failing to make up his condition was obliged to drop the subject at the middle of the second term. At the annual examinations none were conditioned, no one obtaining a lower mark than fifty per cent. The drawings of the students were also examined and marked at the Semi-Annual and Annual examinations. The following is the paper given at the Annual examination: —

ANNUAL EXAMINATION.

Theory of Drawing.

May, 1875.

1. Construct a diagonal scale of three inches to the foot, from which sixteenths of an inch can be taken.

2. On a given line construct a semi-oval, which shall pass through a given point on the bisecting perpendicular of the given line.

3. Construct the projections of a line two inches long, when it is oblique to both planes of projection.

4. Construct the projections of a vertical circle seen obliquely.

5. Find the intersection of a vertical cylinder with a horizontal one, whose axis is parallel to the ground line. Develop one of the cylinders showing the curve of intersection.

6. Find the shadow of a vertical cylinder resting on the horizontal plane, when it falls on both the horizontal and vertical planes of projections.

7. Find the shadow of the floor of a bridge upon the concave surface of a vertical abutment whose plan is shown on the blackboard.

8. Draw the isometric of a cross and pedestal. Also the isometric of a circle on the face of a cube.

9. Draw the isometric of a rectangular pyramid, and find its shadow. Show all construction lines used.

10. Construct by means of three planes, the perspective of a triangular pyramid and its shadow.

11. Construct by the method of diagonals and perpendiculars the perspective of a cross.

12. Find the perspective of a cube by the method of lines in parallel sets, or by vanishing points, and find the perspective of its shadow by the method of vanishing points.

Respectfully submitted,

H. N. MUDGE,

Instructor in Mechanical Drawing.

DEPARTMENT OF DESCRIPTIVE GEOMETRY, STEREOTOMY AND DRAWING.

To the President: —

The preparation of this third annual report has been a pleasure, as well as a duty, owing to the marked gain over previous years, particularly in the firmer establishment of wholesome traditions and usages. These traditions and usages, and the spirit of mutual ambition and co-operation in which work may be done, form, as hardly need be said, an unwritten law, more influential upon the quality and amount of work done, than formal rules and prescriptions can be, and one which has found a happy illustration in my work, generally, of the past year.

Being otherwise fully occupied, my personal attention to the *first year class*, during the first half year, was limited to a careful laying out of their work with the instructor, frequent conferences on its progress, and visits to their drawing room to aid and encourage their labors. During the second half, as in the previous year, I shared in the regular class and drawing room instruction, hearing each half of the class one half of the term.

The results of the year's work are on record, and well reward the labor spent by the faithful instructor in securing them. The subjects pursued were, as before, Elementary Drawing Operations, including Free-hand; Elementary Projections, and Perspective, with weekly lecture and interrogative exercises, and frequent drawing exercises.

The conducting of the *Second Year Class* through their Descriptive Geometry, during the first half year, was marked by the first use of my new text book on that subject, and by the lively zeal and diligence exhibited by the class in working out as full a programme as the time allowed.

The class had three exercises per week, each, in recitation and drawing, for five weeks, and then two per week for about ten weeks, giving, after loss by holidays and in the opening week, thirty actual class room exercises.

After long experience in teaching the subject, I am perfectly satisfied that at least thirty-six exercises, with ample time for study, are necessary for giving a fairly comprehensive course as a foundation for subsequent applications. And as this raises the question, What *is* a fairly complete standard course in Descriptive Geometry for our more advanced Technical Schools? I will add the following summary contribution towards a discussion of it.

For ten consecutive years, I had given a course whose composition and results were as follows, the number of problems varying from 100 to 109 for the ablest classes.

I. The Point Line and Plane; 21 problems.

II. Developable surfaces (including the developable helicoid) their tangent planes; intersections with planes, and with each other; and developments; 26 problems.

Auxiliary plane constructions upon conic sections, conveniently associated with the preceding; 8 problems.

III. Warped surfaces, representing seven of them, as illustrative of general properties, and for subsequent wants in Machine Drawing and Stone Cutting; 20 problems.

IV. Double curved surfaces, singly, and as usefully combined with each other, or with any of the preceding, either in intersections or tangencies; 19 problems.

Special curves; spiral, cycloidal, helical, for after use in Machine Construction and Drawing; 15 problems; 109 in all.

The aggregate results, taken from the original records, were as follows: Number of examinations in ten years, 20. Number

of students appeared, 565. Total number passed on first examinations, 460. Average per cent. of ditto., 81; varying from 50 to 100 per cent., according to the quality of the class. And here it is well worthy of note, that in the last six of the twenty examinations, an average of 92 per cent., varying from 87 to 100 per cent. of all who appeared, passed. This was doubtless due, partly to higher standards of admission, strictly enforced, partly to improved details and means of instruction, and partly to generous class ambitions not to be outdone.

At our semi-annual examination, now, very properly, as I think, made final, in view of the strict intermediate examinations and other reviews, 42 men appeared, of whom 32, or 76 per cent. passed, on marks of 60 or above. Of 13, conditioned by failure or absence, four have since made up their conditions, four left, and the remaining five, partly on account of numerous other conditions, preferred to make a thorough review during the summer. The work required in the class room was seventy-one problems, in the thirty exercises.

Each student was *required* to draw at least *fourteen inked* figures, in behalf of fully finished practice. Forty-seven men, being all who presented drawings, submitted *twenty-two* inked figures each, on an average, besides an average of twenty-three pencilled figures each; the requirement being that each student should make as many of the latter as possible besides the inked ones.

It is important to add that all of the figures were required to be taken from the "examples" in the book, where the given parts were differently placed from those of the engraved plates, and that most of the inked figures were the larger ones, subsequent to those of the Point, Line, and Plane, and equivalent to from two to four times their number of the pencilled figures.

Turning over the "fifteen" problems, more or less, of "mechanical curves" to the department of Mechanical Engineering, the experience of the past year would doubtless enable a fair representative course of eighty problems to be given, with a high average percentage of success, provided that Descriptive

Geometry could be alternated with other subjects so as to give it three days per week, with the consequent continuity of study so peculiarly desirable when beginning it, during the first five weeks of the term.

Third Year's Class; Stone Cutting. The advance made in this subject towards a desirable standard has been nearly as great as that secured for the descriptive geometry. Occupying four hours per week of the first half year, I was personally present with the class in the drawing room through the whole of that time, and also at some extra hours.

I divided the term into three portions, to give pleasing and useful variety to the exercises. In the first five weeks, each student was required to work from the plaster models, making full working drawings of at least three of them. To provide agreeably for the voluntary element, each man was further, under due limitations, allowed to choose his own models. Some chose winding stairs, or others of like difficulty.

In the next seven weeks an elaborate form of wing-wall was given, embracing a front, partly plane, and partly conical, bed surfaces the same, and the top, with the coping, formed of a combination of mutually tangent warped surfaces, the whole designed as both a tolerably comprehensive review of Descriptive Geometry, and a practicable and handsome masonry structure. This, being a long continuous problem, suffered from the want of continuity in the study of it, coming as it did but twice a week, so that I had to supplement the printed notes of it which I had always found ample, when giving the work in eight consecutive days, by numerous written ones, posted from time to time, and amounting to a full text of the problem. In this way, all thoroughly worked up a task as extended and difficult as has often been spread over a whole term.

The remainder of the term was devoted to the groined arch, drawn twice, and on two different systems, by several. In the system drawn by all, the inner groins alone were straight as seen in plan. In the others, both the outer and inner groins were thus straight. Of the two methods by which the latter

unusual result can be brought about, the one chosen was the simpler, though practicable only within certain limits. In all cases full details were made.

Besides the work done with the First Year Class, and already mentioned, I gave a very satisfactory course in Shades and Shadows to the architectural students and to three others, volunteers, during the second half. An interesting special work in the same period was that with the "special architects," in elementary Masonry and Stone Cutting. Five inked working drawings being required, from five to eight were made, some of them elegantly, and including winding stairs, and other equivalent problems.

All of which is respectfully submitted,

S. EDWARD WARREN.

July 5th, 1875.

REPORT ON THE INSTRUCTION IN PHYSIOLOGY AND HYGIENE, AND ZOÖLOGY.

To the President: —

The lectures on Physiology and Hygiene, thirty in number, are given in the second half of the first year, when the students have acquired such a knowledge of chemistry as is necessary for the comprehension of the most important functions of life, such as digestion, respiration, secretion, and the processes of growth and decay. They are given thus early in the course, because the foundations of health or disease are very liable to be laid when young persons, freed more or less from the restraints and the care of home, associate together for purposes of intellectual and physical training; ignorance of the laws of life in youth may result in premature death or confirmed invalidism in the adult.

The course pursued is as follows: the organs of support, as the bones, ligaments, joints, muscles, and skin; the functions of nutrition, including digestion, absorption, circulation, respiration, and secretion: the function of the brain and nervous system; the laws of growth. Each of these departments has its dangers, and the student is instructed in the warnings given by the various organs that he may in time take measures of precaution. The dangers arising from the skin, the lungs, the muscles, the digestive apparatus; the use and abuse of physical exercise, the necessity of rest for muscles and brain, the importance of nourishing food and pure air, are specially dwelt upon.

The instruction is given by lectures, fully illustrated, and the students are advised to pursue the subjects in standard works suited for general instruction. It is believed that by the attention given to these important laws of life and health, the student may save himself from many painful and dangerous diseases, or, in case of sickness in himself or others, may assist nature in her attempts for his recovery.

The lectures on Zoölogy, also thirty in number, are given in the first half of the third year, based on the previous knowledge of human physiology, and are intended to present such a view of the principles of animal life as every educated person should have, and to serve as a basis for the subsequent lectures on Palæontology which is of such importance to the geologist and mining engineer and the student of natural science. Of course, in thirty lectures such a vast field can be only partially covered, and no attempt therefore is made to do more than to give the elements of the science, such as will display the distinguishing characters of the great classes and their principal sub-divisions, — show the gradual progress in time and development from the simplest protozoön to the highest mammal — and to indicate, as far as may be, the plan of creation, which is equally significant whether we regard it from the Darwinian or the Cuvierian point of view. The lectures are fully illustrated by diagrams belonging to the Rogers collection, and by specimens from the Boston Society of Natural History.

SAMUEL KNEELAND,
Professor of Zoölogy and Physiology.

REPORT UPON THE INSTRUCTION IN PHYSICAL GEOLOGY AND GEOGRAPHY.

President Runkle: —

DEAR SIR: — As no report upon the instruction in this department has been presented before, it may be well, at this time, to briefly notice it from its beginning.

The work began four years ago, with a single course of instruction in Physical Geography and Physical Geology, given to the students of the second year. The plan adopted of teaching in the same course those portions of geographical and geological knowledge, which by nature are inseparably associated, has been the foundation of all the good results thus far obtained. Each examination of the class has furnished additional proof that the students acquire greater accuracy and more completeness in geographical knowledge, by considering the surface features of the earth as the outward expressions which the geological structures beneath them have received through the agencies of geological change. This association of these subjects is one which advancing science is daily rendering more indispensable in any well organized course of instruction in this department, and it is, therefore, one which the Institute should carefully perpetuate.

Although the first results of the instructions given were better than I had anticipated, yet the rearrangement of the different courses of study at the Institute and the introduction of

Political and Industrial Geography as a fourth year study, have made the present results far more satisfactory.

The classes in Physical Geography are so large, that it becomes almost necessary to give a large portion of the instruction by lectures. The students are required to take brief notes in the class and to carefully write them out in full at their rooms. Most of their note books have shown a logical arrangement of topics, a correctness in definition, a clearness in description and explanation, and a fullness of statement, which have been creditable to the students. The course has been so arranged as to give a general knowledge of the subject, rather than a minute one of its details, that it may be adapted to the students of the different courses, and that it may serve as a general introduction to the more specific branches of science.

The class in Political and Industrial Geography, being much smaller and composed of students of the fourth year, a somewhat different method in the instruction can be pursued to advantage. While lectures are given upon such topics as can be better presented by them than by other means now at our service, topics are also assigned, either to the class or to individual members, upon which they recite, giving such information as they may have obtained from authorized sources; and personal observations are sought as much as possible.

This course is designed to teach the association of the earth's productions with certain geographical features, geological structures and climatic conditions. The influences which these productions, together with the physical forces acting in the inhabited portions of the earth, exert in determining or modifying the characteristics of races, nations, habitations, modes of life, industries and civilizations of men, are made subjects of special consideration in this course.

The progress attained in each of these courses has been limited to the more careful arrangement and better presentation of the topics, and to the increasing interest which the students have shown in the work.

To make this department what it should be, room and apparatus are indispensable. The subjects taught are of such a nature that good representations are required for the proper presentation of them. Thus far, however, the illustrations have been those furnished by the instructor, there being no available room for the keeping of such materials. I hope the day may be hastened, when a proper room can be appropriated by this department, where the best maps of various kinds, charts, models and other illustrations, may be safely kept and used for this instruction. Until that time, the progress, if there be any, must be very slow, for the difficulties which now arise are more than the instructor can overcome. May we not even anticipate the day, when we shall have a geographical room so well appointed that it shall be to the geographer, what a museum of natural history is to the naturalist, a repository of such valuable materials and a centre of such instructions, as shall lead the more advanced student and the specialist to seek the opportunities offered. Respectfully submitted,

W. H. NILES,

Professor of Physical Geology and Geography.

THE COURSE IN PALÆONTOLOGY.

To the President: —

The section of Palæontology and special Zoölogy has now a Laboratory which has been fitted up in the basement of the Museum of the Boston Society of Natural History. This room is commodious and is comfortably furnished with cases for the storage of an educational collection. The present collections of Palæontology available for class purposes are considerable and quite efficient, though by no means complete. Considerable additions however, are made every year by the Assistant, Mr. Crosby, as he works over and picks out the duplicates of the collections, which are being prepared for exhibition in the Museum of the Society. There are many forms absolutely indispensable to the system of instruction, which can only be attained by direct purchase and these should be obtained without too great delay. The system of instruction consists in completely illustrating all the more important points of any one lecture, either with specimens or with diagrams, or with both, if essential. Specimens are placed in the hands of the students during the lecture, and they are obliged to make sketches which shall show that they have seen the characteristics described from the rostrum. One would suppose that a very small amount of ground would be gone over in each lecture, and that the compensation for this would be found in the thoroughness with which the main points of the lecture could be comprehended. Such was my own impression until I found to my great surprise,

that the amount of ground covered in any one lesson, was almost equal to that which is usually condensed into an extemporaneous lecture, occupying the same length of time in its delivery. It is evident also, that constant effort for improvement will reduce this difference, and I hope to show that proper manipulation of specimens by the students themselves, not only materially assists them to understand the teacher, but is of great assistance to him in the abbreviation of his oral instructions or descriptions. Of course it will be understood that the system has been principally applied to those who have learned the elements of drawing, but I have had instances of men who knew almost nothing in this direction. Though these could not in any given time usually equal those who had had previous instruction, it was very astonishing to see how quickly they supplied the deficiencies of training, and learned to sketch more or less creditably. A knowledge of the art of delineation is therefore of great assistance in the practical application of this system, but the absence of this knowledge is not an insuperable obstacle, or at least has not yet been found to be so by the writer.

Though the lectures only occupy two hours per week for one term, and the Institute schedule does not allow any time for laboratory work in this department, that is, only about thirty hours in all, the students do get a certain reliable grounding in Structural Palæontology, certainly far more than could be obtained in the same time by the ordinary process.

The examinations are conducted upon a similar principle. There are about twenty questions intended to be answered in writing and covering the whole ground practically and theoretically, and a box containing about ten specimens which must be named, described and correctly referred to their separate divisions. The greater or less success of individuals proves how completely such a system is a thorough test of proficiency. I have known several inattentive and undeserving young men to pass the questions very creditably, bnt never yet has one been able to get through his allowance of specimens, where no special gifts of memory or intellect could supply the place of previ-

ous application. Again I have had one very curious case of a student, who had been very attentive and constantly in his place, but who entirely failed to pass the written part, though the first in his class in the determination of the specimens. Usually the best class of students stand high in both parts, but not infrequently, as in this case, high powers of observation may be possessed by a person with little or no verbal memory, and perhaps only a moderate share of reasoning power. I would most earnestly recommend that some steps be taken by which students may be obliged to spend a part of their time each week in laboratory work as supplementary to the lectures. This is absolutely necessary in order to fix in their minds the principal points treated of in the lectures. There is a certain rawness about the information obtained in the lectures and a certain amount of error which can only be overcome by greater familiarity with the specimens. The least time which ought to be given, would be an hour a week, and with this something might be done to cure this defect. Quite complete collections of the typical forms of animals are in course of preparation, and will be completed in the course of another year as far as it will be possible in the present laboratory. The collections belonging to the Institute, though stored in the building of the Society, are labelled so as to be readily identified, and so also are those belonging to the Society, the duplicates of whose collections are used to a limited extent for the benefit of students.

Of course it will be understood that in such a course as is here described no text books are used. There are most excelent books in existence, but all are either too extensive or simply stratigraphical in their arrangement.

The difficulties in the path of farther progress in this, lie in two directions. The students are at first but very slightly prepared in Zoology, so that they enter upon the course without a sufficient general knowledge of Natural History. This obliges the instructor in Structural Paleontology to make the course much more general than it should be, and forces him to dwell upon the general characteristics of the classes and orders of the

animal kingdom, when he should be dealing more particularly with smaller divisions. Then again, all the instruction in Zoölogy and Palæontology should be preparatory to a course of lectures and laboratory study in Stratigraphical Palæontology. This course is at present entirely deficient, and the student therefore to a great extent loses that which is most important to him, either as a mining engineer or geologist. Both of these courses should be made as long as possible, and should be accompanied by a proportionate amount of laboratory work. At present the amount of time given is wholly inadequate, and the students are necessarily left in ignorance of one of the most essential parts of his preparatory training as a mining engineer or practical geologist.

A. HYATT,
Professor of Palæontology.

REPORT OF THE DEPARTMENT OF GEOLOGY.

President Runkle:—

DEAR SIR:—The courses of instruction in Geology in the Institute of Technology are, as you are aware, in part general and in part special in their character. The relations of Geology to every-day life are such that a certain knowledge of it must now be considered as an indispensable part of higher education. The student of physics, of chemistry and of mineralogy finds in geology the application and the practical significance of these studies, while the student of physical and even of political geography learns how intimately these subjects are connected with the geological character of various regions. Hence it is wisely ordered that in the course of study at the Institute, a certain amount of instruction in geology shall be obligatory for all the students. This is given by a course of thirty lectures in the second half of the third year on Elementary Geology, embracing *first*, a discussion of the objects and the scope of geology and its relations to physical geography, chemistry, mineralogy, botany and zoölogy; *second*, the nature, origin, structure and arrangement of stratified rocks; *third*, the history of the successive rock-formations, their geographical distribution, their lithographical character and their organic remains; *fourth*, the theory of eruptive rocks and volcanoes, and the general principles of geological dynamics.

Of the students of the fourth year, those whose studies are such as to bring them more directly into relation with matters pertaining to geology, have a special course of forty lectures in the first half of the year. These lectures, which are obligatory for Mining Engineers, Metallurgists, Chemists and students in Science and Literature, are also followed by a good number of optional students, including physicists and specials. The subject of these lectures is nominally American Geology, but in its treatment occasion is taken to discuss many matters of general interest much more fully than in the elementary course. The crystalline rocks, both stratified and unstratified, are first considered, and in this connection particular attention is given to their mineralogy and to lithology. In tracing the history and the distribution of the various stratified rocks the principles of geological classification are considered with reference to the developments of geological science both in Europe and America, and the bearings of palæontology are illustrated. The relations between the various geological formations and the great physical features of the continent are discussed at length, and a general view is given of the mineral wealth of the country and of its distribution considered both geologically and mineralogically. These lectures are illustrated by maps, plans and blackboard sketches, and also by a large collection of rock-specimens, with which the students are made familiar. It is to be regretted that there cannot more time be given to the systematic study of these labelled and classified collections, but they are so arranged that students can at all times have access to them, a privilege of which many avail themselves.

In the second half of the fourth year the subject of American geology is farther considered in a course of twenty lectures on Economic Geology, designed especially for the students of Mining Engineering. In this course the ores of the principal metals, coal, petroleum, salt and all other useful minerals are made the subjects of discussion with relation to their geological and geographical distribution in the United States, the modes of their occurrence and their economic importance, the whole, as

before, being illustrated by large collections. The object of this course is to give the student a concise view of the mineral resources of the country.

This is followed by a course of ten lectures on Rocks and Minerals employed as Building Materials, designed for students in Architecture and in Civil Engineering, but attended also by the students in Mining Engineering, it being made to include a farther portion of economic geology. In these lectures the elements of mineralogy and lithology are discussed with especial reference to materials used in construction. Granites, limestones, marbles, sandstones, slates, mortars and cements, and clays for bricks and terra-cotta are here considered both with reference to their nature and mode of occurrence, the manner of working them and their distribution in the United States.

In addition to all these there is given to the students in the latter part of the fourth year, a course of ten lectures on Chemical Geology, in which are discussed the origin of the various rocks of the earth's crust, the formation of mineral veins, ore-deposits and mineral springs, and the nature and source of volcanic phenomena.

The number of students following the course of Elementary Geology last year was forty-five, of which forty-three passed the examination. Of the students of the fourth year, fourteen attended the course on American Geology, and eight the courses on Economic Geology and Chemical Geology, all of whom passed. Eighteen followed the lectures relating to Building Materials and of this number fourteen passed.

No special text-book is made use of in these courses of instruction, but the students are recommended to read Giekie's edition of Jukes's *Manual of Geology*, Dana's *Manual*, and Lyell's *Student's Manual of Geology*.

The general plan and scope of the studies in this department may be seen by the examination-papers for the past year, which are subjoined.

EXAMINATIONS IN GEOLOGY.

Elementary Geology. Third Year.

May, 1875.

I. State the differences between crystalline and uncrystalline stratified rocks, with illustrative examples.

II. Describe the nature, mode of occurrence and principal varieties of eruptive rocks.

III. Define bedding, lamination and slaty cleavage in rocks, and explain the origin of the latter.

IV. Give the great divisions of rocks with regard to life, and illustrate the law of progress in animal forms.

V. Give the history of coal, its origin and mode of occurrence.

VI. Explain the nature of anticlinals and synclinals, and their relations to erosion.

VII. Give the theory and mode of formation of salt-deposits.

VIII. Give the limits of the American paleozoic basin, and its history.

IX. Explain the origin of limestones, of sandstones and of clays.

X. Describe the three great classes of superficial or quarternary deposits.

American Geology. Fourth Year.

January, 1875.

I. What are the great divisions of the Eozoic rocks, and their characteristics?

II. Give an account of the mineralogy of the Laurentian limestones.

III. Give a list of the divisions of the New York system of rocks, and the lithological characters of each.

IV. Give an account of the paleozoic Carboniferous system of Pennsylvania, and of that west of the Mississippi.

V. State what mesozoic rocks are found in eastern North America, and what we know of their fauna and flora.

VI. What do you understand by palæontological, and what by stratigraphical breaks? Give examples of each from the American paleozoic.

VII. Give the history of the granites and of the mesozoic dolerites of New England.

VIII. Give the geological history of the North Mountain of Pennsylvania.

IX. Give an account of the coal-deposits of the Rocky Mountain region.

X. Explain the nature and origin of the drift-phenomena of New England.

Economic Geology. Fourth Year.

May, 1875.

I. Describe the iron ores of the eozoic rocks of the United States; their nature, composition, mode of occurrence and principal localities.

II. Give the history of the various paleozoic iron ores of the United States, with details as above.

III. Give the geological and mineralogical history of the native copper of Lake Superior.

IV. Describe the petroleum wells of Pennsylvania and of Canada, and their geological history.

V. Describe the anthracitic and semi-bituminous coals of the United States, and their geological relations.

VI. Describe the gold-deposits of eastern North America, their mode of occurrence and geological history.

Chemical Geology. Fourth Year.

May, 1875.

I. Give the classification of mineral springs, and the origin of the various classes of waters.

II. Explain the origin of limestones, of dolomites and of gypsum.

III. What is the theory of the formation of iron-ore deposits.

IV. Explain the theory of the origin of beds and of veins of metallic sulphurets.

V. State the three principal theories as to the origin of crystalline stratified rocks.

VI. Give the various theories of volcanic rocks, and the arguments for and against each.

Geology of Building Materials. Fourth Year.

May, 1875.

I. Explain the differences in texture and structure between crystalline and uncrystalline rocks.

II. Illustrate the porosity of rocks, its importance, and the mode of its determination.

III. Describe the bedding of rocks, its meaning and its importance to the builder.

IV. Explain the effect of heat on granites and on sandstones.

V. Describe the nature, character and varieties of marbles.

VI. Explain the structure, and give the characters of roofing-slate.

VII. Describe the differences between pure magnesian and hydraulic limes.

IX. Give an account of cements and asphaltic concretes.

X. Give a description of the clays used for bricks and for terra-cottas.

I may here be permitted to call attention to the straitened condition in which this, like so many other departments of the Institute, is now placed, and which greatly detracts from its efficiency. The single and indifferently lighted room, which now serves alike for lectures and for collections is not adequate for either of these purposes, and is moreover subject to be taken complete possession of, on occasions, for the purposes of the Society of Arts. From the limited accommodations of this room, it is found necessary to assemble the students of the third year in a larger lecture-room, the occupation of which at hours immediately preceding and following that assigned for Elementary Geology, does not permit either of the preparations or of the subsequent conferences, questionings and examinations of specimens which are found so advantageous in the other courses in Geology given to smaller classes in the room reserved for that purpose. A lecture-room sufficient for the larger classes, fitted not with chairs, but with desks at which notes can be conveniently taken, is greatly needed for the department. In addition to this there should be a reading-room with tables where

the students in geology might at all times find for consultation the various text-books, special treatises and state geological reports, the study of which should form a part of the work of the advanced students.

Moreover there is greatly needed for the Institute a proper Geological Museum in which collections should be suitably arranged for study, in glazed cases. The collections belonging to the department and my own large accumulations are, for the greater part, necessarily hidden away in boxes, and require for their utilization a large and well lighted room with table-cases, wall-cases and drawers, in which these precious materials for study can be properly displayed. Finally it is greatly to be desired that there should be some facilities for the study of the applications of the microscope and of chemistry to geology. Proper microscopes, collections of rock-sections and means of preparing sections of American rocks, are required, and with these a special laboratory for their farther chemical study. Outside of the Institute building Professor Hyatt has already been enabled to lay the foundations of a working laboratory for palæontology in the rooms of the Society of Natural History, and this in connection with the scheme I have above indicated would enable us, with adequate pecuniary means, to build up in Boston such a school for geological study as has hitherto been wanting in the country.

Respectfully submitted,

T. STERRY HUNT.

Boston, December, 1875.

BRIDGE AND ROOF CONSTRUCTION.

President Runkle: —

DEAR SIR: — In accordance with your suggestion, we have endeavored to supplement the established course in the department of Civil Engineering with a parallel course of lectures and exercises on Construction.

The experiment has proved entirely successful, and we are able already to see the favorable results of an immediate application to practice of principles derived from theoretical investigation.

In previous years, the time of the students has been so fully occupied with other studies that there was no opportunity to introduce a course of this kind; but with the gain recently made in the time of completing various subjects of study, we are able now to begin with the second half of the third year, the lectures, experiments and excursions which I am about to describe.

After careful consideration and experiment, it has seemed best to adopt an analytic, rather than the usual synthetic method of instruction. First of all, the students are to get a general idea of the structures that they are afterwards to study carefully in detail, and finally to design for themselves. For this purpose, we have made class-excursions, and have examined bridges in this vicinity, noting the prominent features in each form of construction. Then in subsequent lectures, I have shown them the principles that led to the adoption of these

forms in each case; — in short, the students have been shown *why* the bridges were constructed in the manner we found them. Structures similar to those examined are also described, and modifications and improvements suggested.

In this way, the interest of the student is awakened and constantly maintained. He has always a clear idea of the subject under discussion, and is better able to undertake, later in the course, the investigation of the magnitude of stresses in structures with which he has, in this way, been made already familiar.

For example, taking the form of bridge known as the Howe-truss, we observe the manner in which the bridge is built, noting the form and material and method of combining and securing the various parts. In the lecture-room, the first point to bring out is, that in certain localities where wood is cheaper than iron, this form of construction is preferable on the score of economy. Then we demonstrate that the braces must be mainly struts, since wood is better able to resist compression than tension. Flexible models of trusses are also exhibited, showing how the effect of a weight in the centre is transmitted to the abutments through the braces; and we have then three important principles of construction demonstrated and illustrated in this one form of truss, — first, the reason for using wood instead of iron in any particular case; second, the importance of employing it, so far as possible, in the form of compression members; and, third, the purpose of inclining the main braces upwards towards the center of the bridge.

This explains the distinctive features of the Howe-truss, and, since we are not to investigate the actual magnitude of the stresses, it remains only to discover from what simple or elementary form of truss this was derived. Working backwards, we reduce the number of main braces to two, finding the ordinary trapezoidal or queen-post truss, and simplifying still farther, we come at last to a plain beam extending over an opening, with bracket braces running up to it from the abutment below,— a bridge with no lower chord.

This example serves to illustrate sufficiently the general method adopted in explaining the principles of bridge construction, and the designing and building of roofs. In every case where it was possible we have employed models illustrating the form of structure under discussion, and by means of flexible members in miniature, have been able to observe the effect of loads variously applied and distributed. In cases where the structures were too complex to be readily copied in models, we have had recourse to diagrams, photographs and drawings, illustrating some of the best engineering works in this country and in Europe. Many of these works I have visited myself, both at home and abroad, for the purpose of careful inspection and study; and the sketches and measurements obtained in this way have been of great service in illustrating the lectures on Construction.

In no case has it been considered enough to give a mere description of a structure without reference to general and particular principles involved in its design and execution. Each example has been studied and fully discussed in plan and detail, the object being to ascertain the considerations that led to the adoption of particular forms and combinations by the builder, and from these are derived precepts and principles to be applied by the student in other cases.

Reference to the accompanying *resumé* will show that the examples given and discussed have been comprehensive and numerous, so that the student, by this means, must become familiar with existing structures, representing the best designs of eminent engineers, and, in consequence, he has at his command a variety of forms and combination of parts, from which he can choose later in the course, when he is required to design bridges and roofs for himself.

I will add a synopsis of the subjects treated in the lectures given to the third year class.

First Lecture. Various forms of bridges shown by diagrams, briefly explained and the names learned.

The Howe-truss, Pratt-truss, Jones-truss, Whipple-truss, Post-truss, Fink-truss, Bollman-truss, Warren-girder, Lattice and Trellis-girders, Long's-truss, Burr's-truss, Bowstring-girders, Double Parabolic trusses, Hogbacked girders, Pauli-truss, Sedley's cantilever bridge, Continuous girders, Arches, Suspension bridges, Von Ruppert's bridge. — Main characteristics of each form.

Second Lecture. The same forms reviewed and more fully explained. References given of particular examples to be seen of each type. The Howe-truss analyzed and discussed. The elementary forms of trusses from which this originated.

Third Lecture. The Pratt-truss compared with the Howe-truss and similarly treated. Relative merits of each, and prominent defects of both. Elementary forms found as before. From what has been already learned, we deduce the rule for the position of struts and ties as inclined braces, and show by models how each part acts when the model-truss is weighted.

Fourth Lecture. Incomplete structures. How missing members are to be supplied. Abstract of portions of Bow's Lectures on Bracing. Subject of counterbraces investigated.

Fifth Lecture. General and particular defects pertaining to wooden bridges. Iron introduced in combination with wood to remedy these defects. Relative economy of the two methods of construction. Examples of each.

Sixth Lecture. Iron-bridges. Reasons for not employing iron in construction more generally. Recent increase in the number of iron-bridges. Durability and elegance of these structures. Coincidence of theory and practice in designing and building. Results to be derived from the forthcoming report of U. S. Commissioners appointed to test iron and steel.

Seventh Lecture. Iron-bridges continued. Saving in wages of watchmen compared with the interest on cost of rebuilding wooden bridges with iron. Ordinary forms, — I. Cast-iron alone. II. Cast and Wrought-iron combined. III. Wrought-iron alone. IV. Wire-bridges; — general features and characteristics of each.

Eighth Lecture. Cast-iron bridges. Cases in which this material may be profitably employed. Its inferiority to wrought-iron in certain respects and its superiority in others. From this, the arch is found to be a suitable form of construction. Advantages and disadvantages of arches.

Ninth Lecture. Other properties valuable in cast-iron. Durability and facility of taking certain shapes. Figures given in regard to cost of working. Recorded failures of cast-iron bridges. Government prohibition against their erection.

Tenth Lecture. Highway bridges. Most simple form. Result of Hodgkinson's experiments. Opinions of other eminent engineers in regard to ultimate strength. Most economical shape of girder. Girders with parallel flanges — how tested for safety.

Eleventh Lecture. Cast-iron continued. Examples of short-span bridges. I. Simple cattle-pass. II. Nottingham Bridge,— five spans of thirty-five feet each. III. Bridge over the Midland Railway,— one span of thirty-five and one half feet.

Twelfth Lecture. Standish Bridge,— eighty-three and one third feet span. Ten cast-iron half arches forming the roadway — how cast and why. Peculiarities of connections. Full details of construction, with an account of the unusual manner in which the bridge was designed by Barlow.

Thirteenth Lecture. Long spans. Rochester Bridge, by Sir William Cubitt,— one hundred and seventy-eight feet span. How constructed as to casting and connections. Deflection. Quantity of cast and wrought-iron in the whole bridge. Southwark Bridge over the Thames. Report on its resistance to decay since 1819. Nature and amount of the traffic over this bridge.

Fourteenth Lecture. Wrought-iron Bridges. Extraordinary length of spans which have been made of this material. Ratio of depth of girder to length in single and continuous girders. How this ratio is determined. Local conditions affecting the design in certain cases.

Fifteenth Lecture. Usual forms of chord-sections. Objections raised by Calcott Reilly to these forms. His proposed section for chords. Struts and ties,— ordinary forms of each, and manner of connecting with the chords.

At this point, the lectures were interrupted by the annual examinations. It was my intention to have proceeded farther with a detailed description of the bridges in and about London, together with an historical account of these structures, beginning with the building of the Old London Bridge in 994, by the Brothers of St. Mary's Monastery. During the coming

year, the course will be so laid out as to cover a wider range of subjects.

It will be observed that no mathematical investigations are undertaken in this scheme. The nature of the stresses is determined in the structures under consideration entirely by observation of flexible models, so arranged as to show thrusts and pulls in the different parts. This method gives the student a much clearer idea of the subject than can be obtained from mathematical study alone, and places him on a broad and sure foundation for the pursuit of advanced theoretical investigation during the last year of his professional course of study at the Institute.

If the objection be brought that a portion of the instruction is quite elementary in its character, my reply is, that in no other part of our course is provision made for instruction on the subjects I have taken up and presented in this way. Professor Rankine's work, the only text-book at present used on the subject of civil engineering, with the exception of the Field Book, fails to give information on most of the topics treated in this course; and, if left to himself, the student is not likely to acquire a substantial and thorough knowledge on these points by independent reading.

FOURTH YEAR COURSE IN DESIGNING.

Want of time and a lack of preparation were serious obstacles in the way of the graduating class of 1875, during the three months in which they attempted the work of designing structures. It was then that the want of previous preparation by means of a course on Construction during the third year was most keenly felt and regretted, and the labor of students and teacher was greatly increased thereby. In spite of all difficulties, however, some very creditable designs of bridges and roofs, carefully worked out and intelligently planned, were presented at the close of the term.

The present graduating class, at the commencement of their fourth year, have already begun the subject of Designing, and

are, in this respect, nearly four months in advance of other classes.

It is my intention to make this course, during the coming year, much more thorough and comprehensive than before, by giving a greater number and variety of problems to be worked out in the form of designs for bridges, roofs, foundations, etc., such as engineers in the practice of their profession are continually called upon to plan and build.

Thanking you for the personal support and encouragement given me in this work, I am

Very Respectfully Yours,

WILLIAM E. HOYT.

THEORETICAL AND APPLIED MECHANICS.

President J. D. Runkle: —

DEAR SIR: — Until this last school year the Department of Mechanics was unable to derive material benefit from the change made in the courses of instruction a year and a half ago.

The opportunity having presented itself, however, was at once seized to extend the course and to adapt it more fully to the needs of the purely professional departments. The subjects treated were not only those formerly pursued, viz., the Composition and Resolution of Forces, the Conditions of Equilibrium, the subject of Distributed Forces as applied to determinations of centres of gravity and the laws governing the internal stress of bodies; and the main laws of Dynamics, viz., those governing motion, momentum, force, energy and allied subjects as Moments of Inertia, Radii of Gyration, etc., etc., but the course was made to include the ordinary theories of the Strength of Materials as applied to tensile, compressive, transverse, and torsional tenacity; the laws of Deflection of beams and columns, determinations of the stress in granular masses, the method of ascertaining the stresses in Frames, etc., etc.; the formulæ applicable to each of the above cases were deduced and studied, and an attempt was made to devote (as far as possible) special attention, in the case of each student, to the different subjects, according to their relative importance in his professional course. The text books used were the same as hereto-

fore, viz., "Rankine's Applied Mechanics" and my "Notes on Mechanics."

The progress of the class was quite satisfactory, those who were conditioned having subsequently made up their conditions at a re-examination.

The extension of the course above alluded to, without any increase of the time allotted to the subject, has been rendered possible by the fact, that the Calculus is now completed before the Mechanics begins, instead of their being studied contemporaneously as formerly.

It follows that the attention of the student is more fully concentrated on his Mechanics, and also that he is not hindered in his progress through ignorance of the methods of the Calculus which he needs to use.

The changes made in the courses of instruction, together with the subsequent amendments and developments have exerted a very beneficial influence in all the departments, and, among other things, have rendered it essential that the students should acquire in their Mechanics a knowledge of all the theories which depend upon Mechanical laws, that find application in their professional work; and be thus enabled to apply that knowledge readily to the practical cases that may there arise. It is important also that the above should be completed by the end of the third year, so that in the fourth year when the student ought to be wholly devoted to his professional work, he may not be hindered by being obliged first to learn something that he should have had in his Applied Mechanics.

To accomplish this most desirable result, and to adapt its instruction to the special needs of the student in the course he has selected, the Department of Mechanics is doing and will continue to do its utmost; bnt it is evident that in order to obtain a satisfactory result the time now allotted to this subject, viz., three times per week for three-fourths of the third year, is not at all sufficient, this being no more than the time allowed when the instruction was confined to the main principles of Analytic Mechanics.

A number of subjects that should be studied in the Mechanics must now be omitted for want of time. Nevertheless, far more has been done this last year than heretofore, and more yet will be done as soon as the time is allowed; and it is hoped that at no distant day the Professional Departments may find that their students do acquire in their Mechanics those principles, theories, and formulæ which they need to apply in their own work.

Whenever it is found possible to complete the Calculus in the second year and devote three exercises per week to the Mechanics for the whole third year, a step will be taken which will decidedly assist in carrying out the above scheme.

I would also take this opportunity to repeat the suggestion I made to you last year, that in all cases where it is possible for a Professional Department to give to its students the practical applications of the theory immediately after or contemporaneously with their work on the same subject in Mechanics, it is certain that the students' interest will be increased and their progress hastened, both in their theory and practice, as has been shown in a very marked manner in those cases where it has been done. The instruction, as heretofore, is given by lectures, recitations and blackboard exercises, and the computation of numerical and practical examples.

In regard to the special courses given in this department to the students of Mechanical Engineering during the last year, I will state that the subjects studied were as follows:

Fourth year's class — Water Power — Strength of Materials — Link and Valve motions and Thermodynamics.

Third year's class — Strength of Materials — Link and Valve motions and Mechanism.

Second year's class — Mechanism.

The text books used were Professor Rankine's treatises on "Machinery and Millwork" and on the "Steam Engine and other Prime Movers"; Weisbach's Mechanics of Engineering, Maxwell's Theory of Heat, Anderson's Strength of Materials,

Auchincloss' Link and Valve motions, Willis' Mechanism, Goodeve's Mechanism, and Shelley's Workshop Appliances.

The progress of all the classes was very satisfactory, and it is especially the good results derived from the fact that the same subjects are treated contemporaneously from different points of view in these courses, and in the Practical, the Graphical, the Experimental, and the Excursional courses of the Mechanical Engineering Department, that causes me to urge the suggestion made above.

Very Respectfully,

GAETANO LANZA,

Professor of Theoretical and Applied Mechanics.

DEPARTMENT OF MECHANICAL ENGINEERING.

President Runkle: —

DEAR SIR: — No important change has been made in the system of conducting the Mechanical Engineering Department during the past year. The system of study by subjects has increased the number of text-books used. Rankine's "Machinery and Mill Work," Willis's "Mechanism," Shelley's "Work Shop Appliances," Anderson's "Strength of Materials," Goodeve's "Mechanism," Weisbach's "Mechanics," Rankine's "Steam Engine," Wilson's "Treatise on Steam Boilers," Maxwell's "Theory of Heat," Porter's and Richard's "Steam Engine Indicator," Auchincloss's "Link and Valve Motion," Zeuner's "Treatise on Valve-Gear," Francis on Cast Iron Pillars, and Francis' "Lowell Hydraulic Experiments" are used, with other text-books.

Our library has proved to be of great service, and we have occasion to thank heartily many gentlemen for special reports upon special subjects, and for letters containing valuable advice and information. Numerous manufacturing companies and firms have admitted us to their manufactories from week to week, and explained to us with great courtesy and patience the interesting operations which they were conducting, allowing us to return again and again to complete our notes of those operations in minute detail. They have also loaned to us many valuable working drawings, which our students have reproduced and

returned. I am satisfied that some important improvements in our manner of sketching and drawing have been introduced during the year.

Our Mechanical Laboratory has more than justified the expectations had of it, and I do not hesitate to express my belief that the young men who graduated from the department last year have had more actual practice in the use of instruments for testing steam machinery than many experts have had in a term of years.

I take advantage of the late date at which this report is issued, to say, that at the recent test of the Providence Steam Engine Company's Pumping Engine at Hope Station, Providence, seventeen of the students were invited to assist in the test, on account of the experience which they had had in our laboratory. Their careful attention to minute matters of observation, their accuracy, and their endurance of the fatiguing duties of the extended trial, were alike noticeable and praiseworthy.

Respectfully yours,

CHANNING WHITAKER,

Professor of Mechanical Engineering.

DEPARTMENT OF CHEMISTRY.

To the President: —

In the Laboratories for Quantitative Analysis there has been, during the past year, a large and enthusiastic class. The quality of the work done has, as a rule, been good; the amount large, the number of quantitative determinations that have been made averaging more than one hundred per week.

Considerable attention has been given to the analysis of ores and furnace products, and an important part of the work done by the students of Metallurgy, and of Mining-Engineering, during their senior year, consists of the analysis of ores employed in, and products resulting from, experiments performed in the metallurgical laboratory. Such analyses test the quality of the work performed, and will guide future experiments.

There has been a great lack of substances for analysis, the composition of which should be accurately known to those having charge of the instruction. A careful selection of substances, the analysis of which would give an appropriate analytical training for any branch of chemistry, has now been made; several samples of each substance have been collected, and prepared for analysis; a large number of these have been accurately analysed by the instructors in this department; and at present we have a fine working collection, the value of which, perhaps, only a teacher of analytical chemistry can appreciate.

The laboratories, though crowded, and quite insufficient for the present wants of the department, have been put in thorough repair, and have been much improved in minor details. Additional balances have been provided; the jet-aspirators of Professor Richards (Am. Journ., Dec., 1874) have been substituted for the "Bunsen" pumps hitherto employed for filtration and a modification of the same device is employed to furnish air for the blast lamps; increased facilities have been provided for volumetric, and for organic analysis, and for the analysis of copper ores and alloys by electro-deposition. To supply the want of a room for optical work connected with chemistry, a nook, in the metallurgical laboratory, kindly granted to the chemical department, has been furnished with a large reflecting goniometer, by "Meyerstein"; an optical circle, arranged for Landoldt's optical analysis, and also for use as a goniometer or as a spectrometer, by "Meyerstein"; a spectrometer, by "Browning"; a large direct-vision spectroscope, by "Zeiss"; a large inverted microscope, by "Tolles"; a smaller microscope, by "Tolles"; three dissecting microscopes, by "Zeiss" and others; a saccharimeter, by "Soleil"; with the minor appliances for chemico-optical work. But as these fine instruments are crowded into a room less than ten feet square, in which not more than two students can work at a time, they are much less useful than they otherwise would be.

The instruction in chemistry is much hampered by the want of a laboratory for qualitative analysis, apart from the laboratory which is used for the instruction in general chemistry; of a laboratory for organic chemistry; of a laboratory for applied chemistry; of a suitable reading room, where the books of the chemical library may be consulted, and writing done; of a number of small rooms, for the use of special apparatus. There is no room in the present building to meet any of these wants, and till some provision be made, further growth and development seem impossible. Every inch of room at the disposal of the department has been fully utilized, and the writer is at present utterly at a loss to know where to find place for a piece of

apparatus requiring but about four square feet of floor room. Even the private laboratory of the professors has been given up for the use of the students.

In consideration of the above, and of the yearly increasing number of students, and referring to the reports of the preceding year, made by the several professors of chemistry, the department would pray that relief, in some form, be afforded.

In conclusion I wish to add, that much praise is due the students; for their zeal, their sympathy, and their hearty coöperation, have done much to aid in the development of the department. Respectfully submitted,

CHARLES HALLET WING.

NOTE: — Since the above was written, the laboratory for fourth year students, and the balance room, have been destroyed by fire; all the balances, and the collection of substances for analysis, above referred to, were destroyed, and the chemical library very seriously damaged. The books can, with a very few exceptions, be replaced, but it will require at least two years to restore the collection. We are indebted to Professor Cooke of Harvard University, and to Mr. Henry F. Durant of Wellesley College, for the loan of balances for immediate use; and to Cornell University for a collection of analysed substances sufficient for use during the present year.

For the present the fourth year students occupy places in the third year laboratory and in the private room of the professors.

It is expected that the laboratory will be restored and equipped for work by the first of January next.

THE COURSE IN MINING ENGINEERING.

To the President: —

It may be of interest at first to take a short but comprehensive view of the more strictly professional studies in this course, to ascertain the amount of symmetry in their arrangement, and also the advancement that a student is able to make in them.

The student begins his experimental work on entering the school with a course of general experimental chemistry, accompanied by a course of lectures. He then takes up qualitative analysis which is followed by a course in practical mineralogy.

At the opening of the third year he begins quantitative analysis, spending a large share of his time in the laboratory, receives instruction in palæontology, and attends lectures on mining throughout the year, and on geology the last half of the year. The summer vacation, at the close of this year, usually gives him an opportunity for an excursion to mining districts where he can have a chance not only to apply what he has learned, but to settle his mind on many vexed questions.

In his fourth year the student takes up assaying, continues quantitative analysis and geology; lectures on Metallurgy and ore-dressing taking the place of those on Mining of the third year. In the last half of the fourth year his time is mainly devoted to practical work on ore-dressing and smelting, which is at every step checked and controlled by chemical analysis and assaying. The subject for a thesis is taken from the work in the Mining or Metallurgical laboratory, or from works visited during the summer. Classes which have not had the privilege of making an excursion to mining regions during

the third year vacation, will have an opportunity to do so immediately after graduating.

Collateral subjects, and such studies as are calculated to give the student a liberal education, are carried on during the whole of the above course as far as is practicable. The subjects which come directly under the charge of the mining professor are given below in detail.

Instruction in Mineralogy. The subject is taught as far as possible in an experimental way.

Blowpipe analysis is dwelt upon sufficiently to enable the student to detect the common elements. A few specimens are then handled so as to gain a familiarity with, and quickness in recognizing, the physical features common to many minerals, viz., hardness, streak, lustre, diaphaneity, cleavage, etc.

Crystallography is taken up and studied until the class can recognize the crystalline form of the models and also of the minerals of the simpler forms.

Determinative mineralogy is begun at the same time with crystallography. Each student receives fragments of minerals, and determines the name of the species of each from its lustre, fusibility, and special features and reactions as put down in the excellent tables in Professor Brush's recent work on this subject.

The class is now well prepared to handle minerals with a view to become acquainted with the peculiar features of each by inspection with the eye alone. To this end four different reviews are made of the more important species.

A tabular statement showing the contemporaneous order of exercises is here given:

	1st hour of Exercise.	*2d hour of Exercise.*
5 Exercises	Blowpipe reactions.	Blowpipe reactions.
2 "	Physical features.	Physical features.
10 "	Crystallography.	Determinative Mineralogy from unknown fragments.
10 "	1st review of Minerals	"
6 "	2d " " "	"
4 "	3d " " "	"
4 "	4th " " "	"

The Instruction in Mining Engineering consists in a review of the machines, methods and processes, by which the various useful minerals are extracted from the ground and are made ready for the market or the smelter.

Veins, beds and superficial deposits are defined, and the methods of prospecting, boring and searching for them enumerated.

The various tools are mentioned; pick and shovel, schlegel and eisen, hammer and drill, drilling machines, powders, nitroglycerine, fire-setting.

The methods of getting at and working out the mineral; shafts, levels, adits, stopes, wide veins, pillar and stall, longwall, square work, sumps, timbering, walling, dams.

Ore transportation on the level, on the shaft, engines, drums, ropes, cages, back balances, inclines.

Man transportation, ladders, rope hoisting, man engines.

Ventilation, bad airs and their causes, natural ventilation, furnace ventilation, machines, compression, distribution and regulation of currents, lighting, breathing apparatus, machines for testing badness of air, mine on fire.

Pumping, damming, checking, draining, Beam pump, Bull pump, steam pump, other devices.

Surveying a mine, transit, chain, tape, lights, targets, German gradbogen, clinometer, measuring by long wire.

Government of mines, financial, business consideration, causes of failure, mining law and the relations of Government to mines.

The students take notes of all the above subjects and illustrate them with careful pen sketches.

Instruction in Assaying. Each student has twelve or fifteen exercises at the assaying furnaces, learning to assay ores of silver, gold, lead, iron, tin and sometimes of copper and antimony. In these he has the opportunity of learning how to manage a simple fire, and the management of different fuels, coke, anthracite, Cumberland coal and charcoal.

Instruction in Ore Dressing and Smelting. The student is now fully prepared to begin practical work upon the extraction of metals from their ores. He receives an ore just as it comes from the mine and is expected to extract the metal from it in marketable form.

The experimental work of the laboratory is carried on by the students under the immediate supervision of an instructor, a sufficiently large quantity of ore being assigned to the student (from one hundred pounds to a ton) according to the quantity on hand and to the work proposed to be done. He first examines it for its component minerals, sorts and samples it, determines its character by analysis, from which he obtains the mineral percentage composition, and its value by assays. He also makes such other preliminary examinations as may serve to indicate the proper method of treatment. He then treats the given quantity, testing all his products at each step of the process.

These tests may be of two kinds:—(*a*) Commercial, in which case he assays all his rich and waste products alone for the metal under consideration, and thereby ascertains the percentage of metal saved in the rich products and that thrown away in the poor refuse products. He can tell at any time whether a rich product has been concentrated up to his smelting standard and whether a poor product has been sufficiently robbed of its metal to admit of its being thrown away. (*b*) He may make scientific tests of the machines and furnaces. Knowing the percentage of minerals in the ore started with, he may watch these minerals all through a complicated system of ore dressing by determining the principal mineral constituents of each product. After such a study he will have very good grounds for conjecture as to the efficiency of his machines for any other ore. In the case of a furnace his scientific tests will seek to find the chemical composition of all the ingredients that are put in the furnace and also of the slags, matts and metal which come out of the furnace. The tests will enable him to regulate the ingredients fed to the furnace so as to produce the slag which shall

have the least inclination to absorb and waste the metal, and which shall not badly attack the firebricks of which the furnace is made, and finally which shall run well or hold its liquidity for a sufficiently long time to effect good separations between metal and slag.

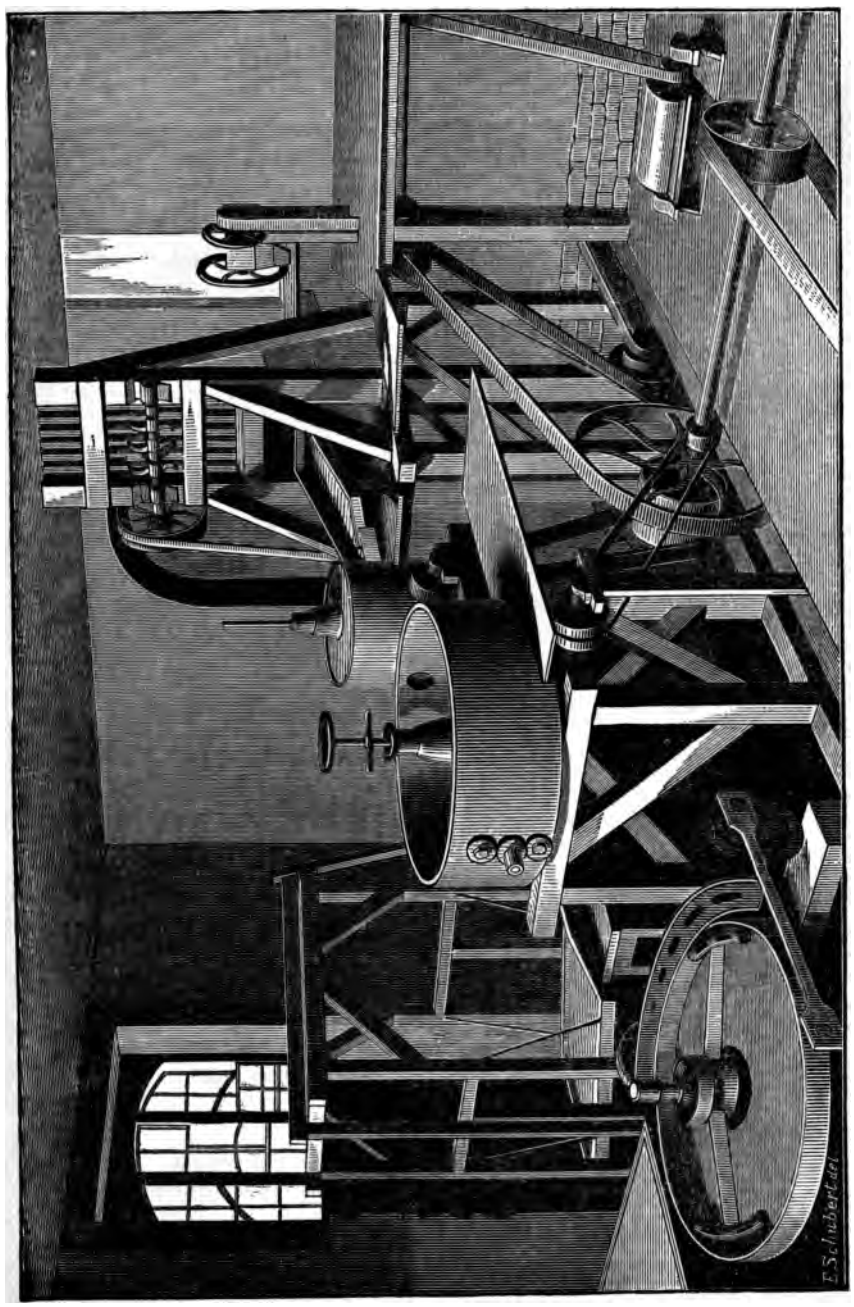
The mining machinery in this laboratory is supplied with power from an upright tubular boiler, which is fed with hot water by a force-pump and steam water-heater, by a ten horse-power engine. There are two suites of milling apparatus: —

I. A small five-stamp battery, capacity 100 lbs. of quartz per hour, of the form in use in Colorado and on the Pacific coast, an amalgamated plate, an amalgamating pan, a settler and concentrator of the kind used in the Washoe process in California and Nevada, for the treatment of silver and gold ores.

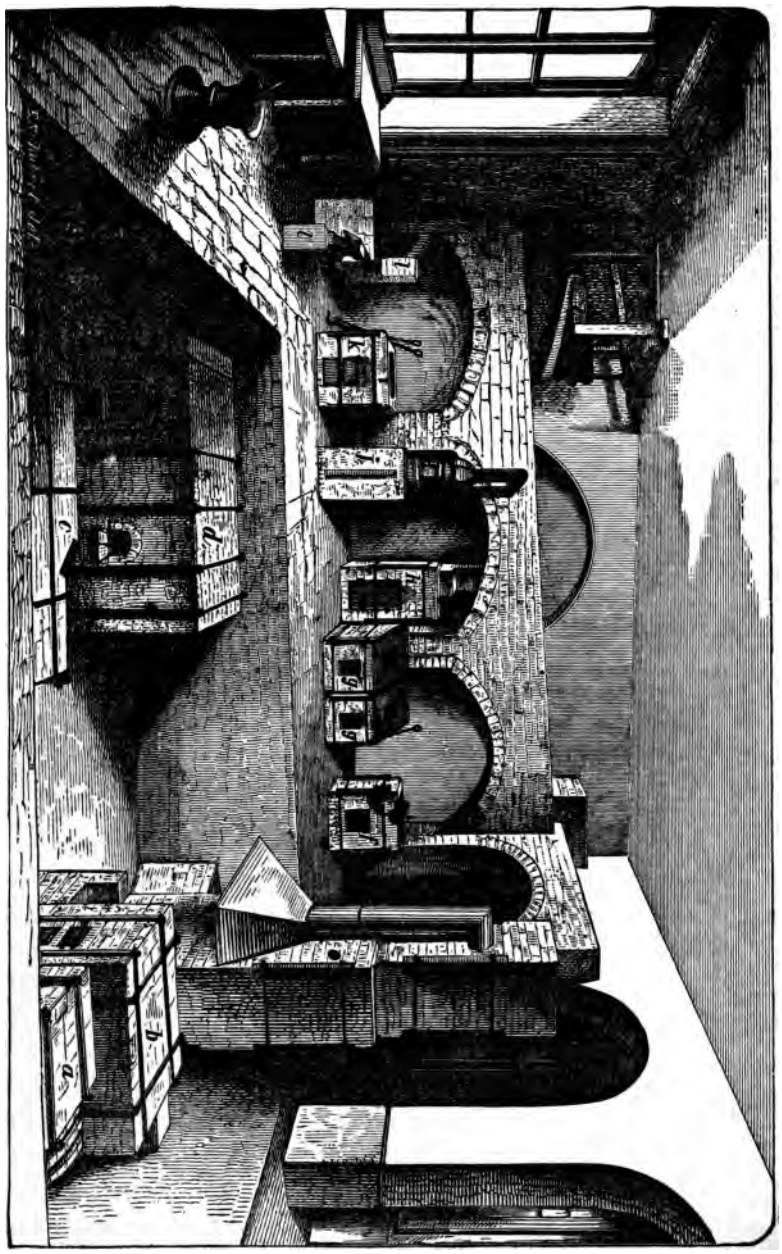
II. A Blake crusher with jaw opening 2 × 5 inches, crushing rolls, capacity 400 lbs. per hour, with automatic screens, a series of sorting V-boxes (German spitzlutte), two automatic machine jiggers, a Rittinger shaking-table, a Freiberg shaking-table, and a set of little finishing V-boxes.

These machines are all arranged to give up their overflow sand into hand buckets, and the overflow water into a large tank. The water from this tank is forced back into the feed tank and used over again. This arrangement makes it possible to perform an experiment without the loss of slime due to an overflow of waste water. Steam drying tables are at hand to dry the wet sand for the furnace. The laboratory also contains the following auxiliary apparatus: — a Whelpley and Storer pulverizer, an edge-stone mill, a Sturtevant blower, and Batchelder's dynamometer. The metallurgical laboratory contains a blast furnace, a reverberatory smelting furnace, a roasting furnace, a furnace for cupellation, furnaces for fusion, crucible and muffle assay furnaces, a blacksmith's forge, and a melting kettle.

The Institute is from time to time receiving ores of gold, silver, lead, copper, antimony, zinc, iron, etc., from various lo-



MINING LABORATORY.



METALLURGICAL LABORATORY.

calities on this continent. These ores are worked, and reports sent to those who contributed them; and it is hoped that by such coöperation the laboratory will continue to receive the necessary amount and variety of ores.

The Course in Metallurgy. During the second year the studies of the courses in Mining Engineering and Metallurgy are the same, except that the mathematical studies in Mining Engineering are replaced by chemistry, in Metallurgy. In the third year the lectures on mining and applied mechanics given to students in Mining Engineering, are replaced in Metallurgy mainly by quantitative and industrial chemistry. With these exceptions the courses are the same during the four years, and although what precedes relates more particularly to the course in Mining Engineering, it will readily be understood to what extent it also includes the course in Metallurgy.

MINING EXPEDITION TO NOVA SCOTIA.

A party of ten students with two of the professors left Boston, by the St. John steamer, on Monday, June 7th, and spent three weeks in visiting some of the mines and mineral localities of New Brunswick, Nova Scotia, and Maine.

Arriving on Wednesday, at Dorchester, N. B., we crossed the four mile ferry, at high tide, to Hopewell, and succeeded, at a late hour, in obtaining conveyance to the Hillsborough Albertite mine. Here occurs that peculiar bituminous mineral whose origin and classification has caused so much dispute among geologists. The highly inclined strata are mostly of a soft, shaly character, and the difficulty of locating the shaft of a mine in such yielding materials is well illustrated by the experience of the miners. The present working shaft, though at the distance of two hundred feet from the vein itself, is found to have been moved a little already by the comparatively quick filling in of the worked out parts, while three different shafts

have before been abandoned on account of this unavoidable creeping. As the Albertite is highly prized as a means of enriching coal gas, it is desirable to send it to market in a state of purity. It is therefore, carefully washed at the mine in long sluices to free it from a slight accidental contamination of pyrites and shale. The stoping of this very brittle mineral is effected with less labor than that of any other substance procured by mining. At times no tool is needed to dislodge it, but the fragile solid breaks up of itself when a barrier is removed, and flows out with an inconvenient rush. Mr. Wm. Blacker, the agent, and Mr. Byers, the mining engineer, were very kind in their attentions, giving us full opportunity to see all that our between tides visit would allow, and fully explaining the nature and working of the mine.

We left the railroad again at Maccan and went by stage to the Goggins. At the Goggins mine a seam of coal about five feet thick and inclined at an angle of about 35° is worked very systematically by "back balances." The pillar and stall method is carried out in such a way that the roof is allowed to fall in, after almost all the coal in each panel has been hoisted to the surface. The strata among which the coal occurs are wonderfully rich in large and well preserved fossils. The high, precipitious bluff, extending many miles along the shore of the Bay of Fundy, shows a complete section of the tilted coal measures several thousand feet thick. There is here a chance to study every leaf of a huge geological book. The special features of this region were carefully explained to us by Mr. B. B. Barnhill, a former student of our Institute.

Going on to Londonderry we spent a day at the Acadia Iron Works and the mine two miles distant. The whole property is now owned by the Canada Steel Co., Limited. The iron belt extends some thirty miles east and west in the Cobequid range. The ore is chiefly limonite, occurring promiscuously, mixed with ankerite and siderite, in irregular veins and pockets nearly vertical. The limonite, which is in various states of aggregation, is probably the result of the slow oxidation and hydration

of ankerite, a double carbonate of iron and magnesium. The Company has in operation a charcoal blast furnace, and is intending to build a high furnace for coke. Large preparations are also in progress for the manufacture of wrought iron and steel by the Siemen's direct process. The coarse ore from the mine is reserved for the blast furnace, while the fine, which has heretofore been rejected as useless, is sifted to free it from dirt and then forms an excellent material to supply the Siemen's furnace. In the new process, the rejected slack of the coal mines is mixed with this fine ore to effect the reduction. So from two refuse materials the Company expect to make iron and steel of good quality; and at the time of our visit, some excellent wrought iron had already been made in this way.

The Pictou coal region was next in order. The coals are mined near Stellarton and mostly taken by railway eight or ten miles to the port of Pictou for shipment.

The principal mines are the Albion, Acadia, Vale, Black Diamond, and Drummond; the latter noted for the fire which occurred in it in 1872.

The Albion mine is worked upon a vein 39 feet thick by the pillar and stall method, with back balances 150 yards apart. These workings, however, only remove the upper nine feet of coal, and they rest upon a two feet seam of slate. The remainiug 28 feet of coal is left for future working.

The Ford shaft is 980 feet deep and has a hoisting engine of 75 horse power and two large cages, one of which goes up while the other goes down. The men are all lowered into and hoisted out of the mine by means of these cages. Each cage has two platforms and accommodates 20 men, and makes the descent in 70 seconds. The engine lifts 4,800 pounds of coal at once and makes the trip of 980 feet in 45 seconds. The water is pumped from the mine by an upright engine of 260 horse power, which raises 95 gallons at a stroke and makes seven strokes per minute. The mine is ventilated by a large suction rotary fan wheel 30 feet in diameter, 10 feet wide, run

at 45 revolutions per minute in dog-day weather when the mine is hard to ventilate. This rate is equivalent to 90,000 cubic feet of air drawn per minute, which is the amount required by 20 horses, 290 men, and for the removal of the fire damp. The Superintendent, Mr. Hudson, very kindly extended to the party the privileges of the mine, and his son devoted his time to us in the exploration of this mine and the Cage pit, which is worked by the same Company.

In the Ford pit we had the uncommon experience of walking about underground, several miles, through dry, spacious levels, by the dim light of safety lamps, each of the party carrying one.

At Gay's River, seven miles from Schubenacadie, on the Intercolonial Railroad, is a very peculiar deposit, carrying gold. It is a conglomerate which has been pronounced by geologists to be as old as the carboniferous era, and as sedimentary deposits carrying gold are usually supposed to have derived that metal from the rocks from which their own pebbles came, this deposit gives a hint to the geologist that the veins originally carrying gold are pre-carboniferous. This ore yields from four to six dollars a ton, crushed by stamps and run over amalgamated copper plates.

The fourth of July was passed in Halifax, each one spending the day according to his own pleasure. A part of us went to several spots of much geological interest under the guidance of Dr. Honeyman, who assured us that the different rock beds of Nova Scotia are so well defined that an expert could locate almost any of the pebbles found in the gravel beds of Halifax. The doctor picked up pebbles which he identified as coming from the Cobequid hills, others from the amygdaloid beds of Blomidon, and still others from various places.

The Montague and Waverly gold mines were visited on the way to Windsor. But little work is now being done at either of these mines. At Montague a large number of specimens which showed visible specks of gold were found by the party. The impression gained from both these mines was that the

veins are narrow, six inches or less of quartz, but that they seem to make a good show of gold per ton of vein stone. Capital does not seem to have been much attracted here, whether from lack of confidence in the mines or in the men, or from want of proper representation, we did not ascertain.

The Windsor plaster quarries are well worth a visit from a mineralogist. Beautiful selenite crystals are found there beside ulexite, howlite and anhydrite. Cape Blomidon, celebrated for the beautiful trappean minerals which have come from it, could be reached from Windsor only by chartering a special steamboat for the trip. The mineral beach is thirteen miles long and it is said to be entirely a matter of luck whether or not a party may land at a spot which is abounding in good specimens. The minerals which are sought here, occur originally filling cavities in the trap. The trap crumbles and falls off the cliff in the spring as the frost melts, and the most perfect minerals are obtained then. Fine specimens of stilbite, hewlandite, scolecite, amethyst, and laumontite, were found by the party.

Returning by way of Annapolis to St. John, we made way with some little trouble to the Lake George antimony mines, which are not worked at present. There seems to be no lack of ore and the mine is well equipped with machinery and furnaces. The mine has been through various vicissitudes in having men who were skillful in some respects, but unable to adapt their knowledge to the needs of the country. Some of its superintendents were expensive in one thing, some in another. And so an apparently valuable property is lying unused awaiting a prudent, economical management.

Our work of observation was finished by an interesting trip from Bangor to the Katahdin iron works, situated 19 miles from Milo, a small town on the Bangor and Piscataquis Railroad. They have a charcoal furnace in successful operation and are turning out a good quality of iron. The ore deposit is one of peculiar interest to the geologist. It is apparently of recent age and is still in process of formation. The trees growing on

the deposit are mostly aspens and birches, which do not seem ever to have attained a diameter of over six or eight inches although undisturbed by man. When they have reached about this size they have fallen, and become changed by the chalybeate springs, into iron ore, to be followed in turn, by the succeeding crop. A large proportion of the ore which constitutes superficial beds from two to nine feet thick is composed of fossilized leaves and limbs of trees which are so well preserved that the species can be identified at a glance.

The thanks of the party are due to Mr. W. B. Hazeltine for his kindness in giving reduced fares on the Boston and Bangor boat, and to Mr. H. D. McLeod for reducing the fare from St. John to Bangor. These helps often times enable students to go on these expeditions who otherwise could not do so.

ROBERT H. RICHARDS.

LOWELL FREE COURSES FOR 1874–75.

General Chemistry. Twenty-four laboratory exercises.
Qualitative Analysis. Twenty-four laboratory exercises.

President J. D. Runkle:—

DEAR SIR: — For the last few years the Lowell Courses in Chemistry have consisted of Laboratory Exercises in General Chemistry and in Qualitative Analysis. One winter a course of lectures was given, but experience then and since has seemed to show that more good can, on the whole, be accomplished by laboratory exercises.

The number of tickets issued is, of course, limited by the size of the laboratory at my disposal. The number of applications is very greatly in excess of our accommodations, but many of the applicants have no appreciation of the nature of the course and if they receive tickets, either make no use of them or, after attending for a few exercises, appear no more. Others who would profit by the course are thus prevented from attending. As we have this same trouble year after year, I would respectfully suggest that applications for the courses in Chemistry be made in person.

The majority of the persons who avail themselves of the opportunities offered are school-teachers and practicing pharma-

cists, although these two classes are not the only ones represented: the two sexes are represented about equally.

In General Chemistry, those who are beginning the subject use Eliot and Storer's Elementary Manual, and perform, each for himself or herself, the experiments there described; those who have previously studied the subject experimentally proceed from the point already reached. In order to derive any profit from the course it is necessary that time be given to the study of the subject outside of the laboratory, and only those who take sufficient interest in the matter to be willing to devote the necessary time can expect to be benefited by the laboratory work. In Qualitative Analysis each person works independently of every other, and the progress made depends upon the individual. Except the beginners, who use a prescribed text-book (Eliot and Storer's Manual), the students use any book with which they are more or less familiar, and the selection of substances analyzed is made, as far as possible, with a view to the occupation of the student or to the use he or she is likely to make of their knowledge.

The class of 1874–75 numbered forty-five in all. No account was kept of the individual attendance, but the number present at each exercise was about thirty-five on the average. With some of the more advanced members of this class, I tried an experiment to see how much it might be possible to accomplish in *Quantitative Analysis* during such a course of twenty-four two-hour exercises. We labored under many disadvantages for lack of proper space and on account of the shortness of the exercises; but, in spite of this, the results were very satisfactory. Those who pursued this course (all ladies) acquired an idea of the general principles of gravimetric and volumetric analysis and of certain parts of stoichiometry, and had some practice (limited to be sure), in the application of the principles to special cases. It seemed, however, impracticable, with our present laboratory accommodations, to undertake regularly a "Lowell" course in Quantitative Analysis, but for the class

of persons from whom, at present, comes the greatest demand for such instruction, namely, the teachers, provision has this year, 1875–1876, been made by the Institute.

Yours Respectfully,

WM. RIPLEY NICHOLS.

Practical Geology of the United States. Eighteen lectures.

President Runkle : —

In the months of November, December and January, 1874 —75, I gave an evening course of free lectures on the Economic Geology of the United States, of which the following is a synopsis : —

I. Preliminary notions of geology and the classification of rocks and formations.

II. History of granites and granite-like rocks.

III. The crystalline stratified formations.

IV. History of mineral veins and ore-deposits.

V. The Paleozoic formations, their origin and history.

VI. The Mesozoic and more recent formations.

VII. Relations between the geology and the physical geography of the United States.

VIII. Building-stones ; granites.

IX. Marbles, sandstones and slates.

X. The iron ores of the crystalline rocks.

XI. The iron ores of the paleozoic rocks.

XII. Copper ores and mines of native copper.

XIII. Gold and silver mines.

XIV. Salt, and gypsum ; mineral waters.

XV. } Coal deposits, history, development, economic importance.
XVI. }

XVII. Petroleum and its geological relations.

XVIII. The recent deposits ; soils and clays.

The object of these lectures was to give in the first place such notions as would serve to make intelligible the great fea-

tures of our geology and the relations of these to the physical geography of the country, and in the second place to describe our mineral resources, their geological history and their economic development. T. STERRY HUNT.

Lantern Projections. Eighteen lectures on the use of the Lantern as a means of illustration in teaching.

President Runkle: —

The course of lectures in Lantern Projections was designed especially for teachers who wished to use this valuable means of illustration in their daily work. The ground covered was substantially as follows: Sunlight, description of the *porte-lumière* and various forms of heliostats. The magnesium light, method of making and burning magnesium. The calcium light, methods of making oxygen and hydrogen, methods of storing by gasholders, reservoirs and bags. Various forms of burners, substitutes for the lime cylinder, the Bude light. The electric light, regulators, forms of batteries, theory of their action, magneto-electric machines. Photometric measurements of the various lights. Experiments with the direct light, shadow and penumbra, phosphorescence and fluorescence. Theoretical considerations involved in the methods of projections, refraction, lenses, chromatic and spherical aberration. Construction of the lantern, various forms of condensers, their advantages and defects. Forms of projecting lenses, size of image, forms and dimensions of screens. Objects employed, drawing and painting on glass and gelatine, photographs. Projecting small objects, opaque objects, Chinese fireworks, chromatrope, dissolving views. Stroboscope, application to revolving wheel, tuning fork and electro-magnetic engine. Tanks, three methods of exhibiting chemical decompositions, convection, capillarity, electric decompositions, crystallizations. Vertical lantern, magnetic phenomena, waves, cohesion figures. Galvanometers, method of projecting objects in two planes at once, mirror galvanometers.

Lissajous' experiment, compound pendulum, Crova's apparatus. Lantern microscope, precautions and defects. Polarization of light, theory of apparatus employed, parallel beam, selenite plates, compressed, bent and unannealed glass, converging beam, crystals, mono-chromatic light. Spectra, method of projection by sunlight, calcium and electric light, spectra of metals, reversion of soda flame, monochromatic light, imitation of spectra with black lace curtains. The lectures were fully illustrated by various forms of lanterns, and the object aimed at was not merely to describe and exhibit the various phenomena, but to explain how the apparatus should be made and arranged and what precautions were essential to secure success.

E. C. PICKERING.

Elementary French. Eighteen lessons.

President Runkle:—

I have the honor to submit to you the following report on the work assigned to me in the Lowell Evening courses for the winter of 1874–75.

Beginning on the 16th of November, 1874, our exercises took place, without interruption, on the Mondays and Wednesdays of every week, until brought to a close on the 13th of January, 1875. The class on the opening night numbered in the eighties; in the few succeeding nights, however, this number gradually fell off, until it reached a steady average of about fifty persons, who remained, to the end, assiduous attendants.

While adhering strictly to the letter of the programme, I availed myself of what freedom was left to me in the arrangement of details, selecting out of the topics included under the general head "elements" only such as appeared to me to be more important or more appropriate to my audience; thus, I left out many minor points, sketched others with a rapid outline and endeavored to set off among all others the characteristic parts of speech, the *pronoun* and the *verb*. There, in fact,

is found whatever originality or richness of forms the French has inherited from the Latin, and there also the student meets with most difficulties. Besides, the treatment of these two topics carries with it several questions of syntax, such as the construction or position of the different parts of the sentence, the arrangement of words in negative or interrogative clauses, etc., all of which points pressed themselves upon our attention and furnished us with an abundant material until the very last minute. Each exercise was divided into two parts: 1. A summary exposition of the topic on hand, with illustrations on the black-board. 2. An application of the principles and rules thus announced, by means of sentences given out to the students during the last twenty minutes of the lesson, to be translated into French and written down while the explanations still rang in their ears. These translations were handed in on leaving the class, carefully examined between the exercises, and the errors pointed out at the opening of the next lesson. In this way I was enabled to follow the progress of the class and to hasten or slacken speed as the case required. I may add that these papers, for the most part, did honor to the earnestness of purpose as well as to the understanding of the writers.

A course in "Elementary French" must needs include exercises in *pronunciation*. Here again we had to follow a short cut method; the study of pronunciation is a laborious process whereby the student's ear is inured to strange sounds and the clumsiness of his organs overcome; all this requires time and a constant, personal commerce between the teacher and the pupil; as we were limited in regard to both requisites, I restricted myself to exposing clearly the scheme of French sounds and the peculiar structure of the French syllable; then, I requested the class, as a unit, to scan aloud some of Lafontaine's fables, keeping time, giving out every sound distinctly and articulating each syllable as if it were a word in itself. The class brought to this very simple, almost childish, exercise, so much good will, that it was pursued, to the last, for a few minutes in each lesson, and we trust, not without profit, since

the students were thus taught a stringent observance of the syllabic division of words, a principle of utterance too often disregarded in our hasty methods.

A last remark, with quite a different bearing, I must also submit to you, Mr. President, as it goes far towards explaining what success the class may lay claim to, namely; although the French course is intended for persons desirous of beginning the study of that language, such real beginners form but an exceedingly small percentage of the entire attendance. In fact, without any previous training, a person is at a disadvantage in so large an assemblage. I hesitate to say that there were none of that class; yet, barring other proofs, a careful examination of the written translations bears witness to the fact that a very large majority of the students had studied French, whether at school or under private tuition, before joining our course. With such scholars alone could our hasty march find favor and for such ones, mainly, be fruit-bearing; it was for them not a new, hardship-like study, but a mere review of things and facts previously known. Whether this unrequired preparation of so great a majority of the attendants ought to be taken in consideration in the shaping of a subsequent course is a point which I must, Mr. President, leave to your consideration.

Yours, Very Respectfully,

JULES LUQUIENS, *Instructor.*

December 20, 1875.

Modern Philosophy, from Descartes to Hegel. Eighteen lectures.

President J. D. Runkle: —

This series of eighteen Lectures was attended by some forty persons, about a third of whom were women. Fifty-four were present at the first lecture; at the last, there were thirty-five.

The following is a synopsis of the course: —

Lect. I. *Introductory:* The Definition of Philosophy, the Group-

ing of the Historic Systems, and the General Character of the Modern Movement.

Lect. II. *Descartes:* his Epoch, his Genius, and his Claims as Founder of Modern Philosophy.

Lect. III. *Descartes*— the Details of his System: an explicit Dualism, but at the same time an implicit Monism; its inconsistency as Dualism, its consistency as Monism.

Lect. IV. *Geulinx, Malebranche, Hobbes:* Attempt, by the two former, to save the Dualist view of Descartes by the added theories of *Occasionalism* and *Vision in God;* by the latter, to bring out the required consistent Monism by the theory of *Materialism.*

Lect. V. *Spinoza*— General Estimate: Cartesian implicit Monism made explicit as Pantheism.

Lect. VI. *Spinoza:* Outline of his *Ethics.*

Lect. VII. *Locke:* Transfer of the Problem of Philosophy from the question of the Nature of Being to that of the Scope and Worth of Thought; Beginning of Empiricism, and preparation for Skepticism in the empirical Principle.

Lect. VIII. *Leibnitz:* The Revolt from Empiricism, and Return to the Question of Being; Preparation for Idealism in the *Monadology,* a system of an infinitude of *Substances* made one in *Essence* by the Pre-established Harmony.

Lect. IX. *Berkeley:* Idealism becomes explicit in the form of a Dualism of Spiritual Substance, Creator and Creature; the Insubstantiality of Matter as a corollary of Empiricism.

Lect. X. *Hume:* Return to the question of the Worth of Thought; thorough comprehension of Empiricism as in reality Skepticism.

Lect. XI. *Reid, and the Scottish School:* Revolt from Skepticism in the interest of Common Sense; Hypothesis of the Transcendental origin of the Principles of Common Sense.

Lect. XII. *Kant:* The Transcendental principle comprehended; the transcendentalism of Common Sense vanishes in Kant's Transcendental Skepticism, as Empiricism completed itself in Hume's Empirical Skepticism.

Lect. XIII. *Kant:* His Theoretical Philosophy; the *Critique of Pure Reason* in outline.

Lect. XIV. *Kant:* His Practical Philosophy; attempt to compensate for the skepticism of the *Critique* by the doctrine of *Ethics* and of

Good Judgment; Sketch of the *Critique of Practical Reasbn* and of the *Critique of Judgment.*

Lect. XV. *Fichte:* The removal of Kant's hypothetical "Thing in Itself" converts his Transcendental Skepticism into Subjective Idealism; the Human Ego the only Substance; all else, even God, only the Form and Mode of man's existence; Pananthropism, as inverted Spinozistic Pantheism.

Lect. XVI. *Schelling:* Reaction from Fichteanism, on viewing it as implicit Single-Individualism; Hypothetical identification of Being and Thought; the NEITHER, as abstract Common Essence of Spirit and Matter, proposed as the Sole Reality or Ground of All.

Lect. XVII. *Hegel:* Absolute Idealism; Reality as PERSON, *i. e.,* as the Living Unity in which the twofold of Subject and Object (Thought and Nature) given by Reflection, is taken up by means of the mutual neutralization of its two terms.

Lect. XVIII. *Hegel:* Sketch of the *Logik,* with especial reference to its doctrine of the *Begriff* as the real unit of thought.

GEORGE H. HOWISON,
Professor of Logic and the Philosophy of Science.

Elementary Principles of Mechanism. Eighteen lectures.

President J. D. Runkle:—

DEAR SIR:— The following is a synopsis of the work done in the Lowell free course of eighteen lectures on the Elementary Principles of Mechanism given by me last session. In these lectures, which were intended for persons actually engaged in work in machine shops and in similar occnpations, an attempt was made to present, as far as time would allow, the mathematical principles which underlie a correct construction of the different mechanical combinations and their adjustment to the purposes they are intended to fulfill; and to give such explanations as would enable one to make correctly and understandingly computations and designs for practical cases.

The discussion of Belts and Pulleys and of Gearing occupied the greater part of the time, the remainder being devoted to the study of Cams, Linkwork and Universal joints.

Under the head of Belts and Pulleys, the following were the subjects discussed: —

Advantages and disadvantages of connections made by belts and cords, and cases when it is desirable to employ them. Open and crossed belts and cords. Lacing, splicing and rivetting. Limiting speed and length of wire ropes. Bearing pulleys for wire ropes. Construction of pulleys for belts, cords and wire ropes. Lateral stiffness of belts. Climbing of belt. Crowning of pulleys. Fast and loose pulleys. Quarter twist. Connection of non-parallel shafts by belts, by cords. Guide pulleys. Reversing gears where fast and loose pulley is used. Computations under given conditions of diameters of pulleys, velocity ratio of pulleys, speed of belt, length of belt, etc. Conical pulleys; 1st, Stepped cones, computation of the proper diameters; 2d, Speed cones, determination of swell. Non-circular pulleys. Velocity ratio. Straining pulleys. Fusee. Chain pulleys. Snspended pulleys, etc., etc. Tension on each side of the belt. Coefficient of friction of leather on iron. Strength of belting. Power transmitted by belts. The last four being discussed chiefly in the light of the experiments of Gen. Morin and Mr. H. R. Towne.

Under the head of Gearing the following subjects were studied: —

Computation under given conditions of diameters of pitch surfaces speed, etc., of spur and annular wheels and of rack and pinion. Determination of the pitch surfaces of bevel gears. Screw gearing. Frictional gearing. Non-circular gearing. Eccentric and elliptical gears and rolling cams. Rules governing the pitch and number of teeth. Crown wheels. Hooke's stepped teeth and Hooke's screw gearing. Trains of wheelwork. Computation under given conditions of velocity ratio of gears, numbers of teeth, diameters, etc. Hunting cog. Least number of teeth admissible in a pinion. Proper number of intermediate axes in a train. Idle wheel. Dr. Young's least number of teeth in a train, its advantages and disadvantages. Clock trains. Epicyclic trains. Copying lathe. Screw cutting lathe. Cal-

culation of change wheels. Mangle wheel. Determination of the proper dimensions of the teeth of wheels, viz., Addendum, pitch, clearance, thickness of tooth, working depth, etc. Construction of rolled curves. Instantaneous axis. Mode of designing epicycloidal teeth and of constructing the template. Radial flanks. Curved flanks. Case when circumference of describing circle is six times the pitch. Mode of designing involute teeth, their advantages and disadvantages. Determination of the base circle. Cycloidal teeth for racks. The Odontograph and its use.

The time remaining from the above subjects was devoted to the following, viz, : —

Velocity ratio in Linkwork. Drag link. Link for contrary rotations. Link for reciprocating motions. Crank and connecting rod. determination of dead points, velocity, ratio, etc. Oldham's coupling Hooke's joint. Cams. Eccentrics. Construction of cams to actuate 1st, a rocker arm; 2d, a sliding bar. A *very* brief consideration of the slide valve was also made.

All of which is respectfully submitted.

GAETANO LANZA.

ABSTRACTS OF THESES PRESENTED BY GRADUATES OF 1874–75.

DEPARTMENT OF CIVIL ENGINEERING.

Fall River Water Works. Abstract by the author, Samuel E. Allen.

I. In the introductory portion of this review, I have considered the City of Fall River: — 1st, As regards its location; 2d, As regards its general character; 3d, As regards its available sources of water supply, since all these points have an important bearing on the character of the works to be constructed.

II. I have touched on some of the most important points to be considered in the construction of any work of a similar nature. 1st, Probably the point of most importance is that of adequacy; 2d, Perhaps next to the consideration of adequacy is that of economy; 3d, The third consideration is that of safety.

III. In the descriptive portion of the review, I have taken up the arrangements for obtaining the water supply from the lake, and described the most important of them more or less in detail. These arrangements are, the Gate House, Conduit, Engine House and Pumping Engine, the Force Mains to the Stand Pipes, the Stand Pipes, Supply Mains, Water Gates, Hydrants, etc.

The description is accompanied by three drawings. Drawing No. 1 shows a plan of the Pumping Station, No. 2, a plan and

elevation of the Weir and Stand Pipe, and No. 3 shows a plan, half side elevation, and two sections of a Man Hole and Blow-off.

Lattice Girder Bridge. Abstract by the author, Henry K. Burrison.

This particular design consists of an upper and lower boom to withstand the bending action, and a set of diagonals crossing each other at the middle of each panel, to withstand the shearing action of the load. The span of the bridge is one hundred and ninety-two feet, and consists of sixteen panels; the height is eighteen feet, and width fifteen feet clear; the length of each piece is dependent upon these given dimensions, while the *area* of any cross section depends on the stress at that cross section, and the *form* of cross section on the option of the designer, who is guided by the relative position of each piece and the forms which experience has shown to be best. The diagonals are simple bars of rectangular cross section, fastened to the lower part of the upper boom, which is a square cell set on edge, and the web of the lower boom which has an inverted T shaped cross section; the end posts are square cells.

The material used is wrought iron, except the supports for the I beams which are cast. The sustaining power of the bridge is calculated for a dead load of 800 lbs. and a live load of 1200 lbs. per ft. run. As the girder is composed of two simpler ones, the action of the load is considered on each, and the results combined. The diagonals acting as ties, are calculated for a working strength of 10,000 lbs. per sq. inch, while the struts are determined by Gordon's formula, the greatest action of the load alone being considered in every case.

The I beams which support the floor timbers, weigh 200 lbs. per yd. and are calculated to support, beside the floor timbers, a weight of 20 tons, being the greatest weight liable to come from a locomotive on them. The bolts which sustain them are calculated from the same data, and pass through the flange of the lower boom. The horizontal diagonals for wind bracing,

are calculated from a pressure of 25 lbs. to the sq. ft., acting on a surface 192 ft. by 18. The rivets are calculated from bearing area, the bearing of one square inch being considered as 8000 lbs.

Lattice Girder Bridge. Abstract by the author, C. A. Church.

The first part of the thesis is taken up by a description of the abutments and of their foundations. This is followed by a description of the details of the bridge.

Next is given a general description of the method of calculating the stresses of the diagonals and chords, followed by the calculations of these stresses, and the net area of cross-section required in the different pieces.

The calculations for the number of rivets required in the diagonals and joints of the chords are next taken up, after which the maximum stresses to which the floor is subjected, are calculated, and the sizes of the stringers and cross-girders fixed accordingly.

The last subject taken up is the determination of the weight of the bridge. The weights of the different parts of the bridge are first calculated in order, following which is a table giving a summary of the weights.

Salem Water Works. Abstract by the author, Frank S. Dodge.

I have divided my thesis into two parts, the first relating to the subject of water works in general, and the second to the works belonging to the city of Salem, Mass.

Part first embraces,

1. A few of the advantages of an abundant supply of pure water.
2. An account of some ancient and celebrated aqueducts.
3. The difficulties to be met in the construction of reservoir banks, and the various means of overcoming them.
4. A list of general principles to be followed, and which are essential to the durability of the structure; also the means of preserving the purity of the water.

5. Methods and materials for rendering a reservoir water tight, especially at the joints between puddle and masonry or pipes.

Part second includes

1. A short account of the introduction of water into Salem, with a history of the old "Salem and Danvers Aqueduct Co."

2. A description of Wenham Lake, the source of supply, embracing its situation, capacity, quality of water, etc.

3. A detailed account of the works, beginning at the source, and extending through the whole in the order in which they occur, viz., the iron conduit pipe, gate chamber and screens, brick conduit, pump well (with the difficulties encountered in laying the foundations in quicksands), engine house, Worthington Pumping Engines, force main, check valve, branch main and stand pipe, reservoir, effluent pipes, supply main, and system of distribution.

The reservoir, being very important and difficult in construction, is treated in its minutest details. It is described in its situation, elevation, capacity and construction of its parts, including puddle floor and walls, paving of slopes, effluent pipes with their screens, and supports within the embankment, and the system of surface drainage.

The whole is illustrated by fifteen tinted drawings covering the most important points, and briefly explained in an appendix.

The Iron Bowstring Girder Bridge over the Charles River at Waltham, Mass., by the author, Edgar S. Dorr.

In this thesis I have first presented a description of the bridge and its details from measurements made by myself and others, and from information obtained from the builders, the King Bridge Company of Cleaveland, Ohio. From these data I have calculated the weight of the bridge, and thus obtained the fixed load. The live load for which the bridge was calculated, was given me by the engineers as seventy-five pounds per square foot, the bridge being a road bridge. With these

data I have calculated the greatest thrust at the crown of the bow, and the greatest tension in the main tie, by the formulæ of Rankine, p. 563, Art. 379. By the formulæ of the same article I have calculated the tension and the thrust, if any, in the verticals, and the tension in the diagonals produced by the rolling load. In each case I have computed the dimensions of the pieces necessary to resist these stresses, and compared them with the actual dimensions of the bridge. I have also calculated the strength necessary in the cross beams to support the platform and its load, and the strength of the various joints of the bridge.

I have also made two drawings, one representing the bridge in elevation, plan, and end view, and the other giving details of the bridge upon an enlarged scale.

The Howe Truss Bridge at India Point, Providence, R. I.
By William C. Edes.

(Abstract not received.)

Tunnelling. An abstract by the author, Edward A. W. Hammatt.

I have treated this subject under the following subdivisions: — 1st, Preliminary Work; 2d, Sinking Shafts; 3d, Transferring the Line and "dropping" the Levels down the shaft; 4th, Driving Headings; 5th, Excavation and Brickwork of Side Lengths; 6th, The same of Shaft Lengths; 7th, The same of Leading and Junction Lengths; 8th, Centre, and then a few statements in regard to Machine Drills.

I have illustrated my description by sketches in the body of the thesis, and by two plates of drawings, and as the operations of tunnelling in rock consist mostly of blasting and quarrying, I have confined my description to tunnelling through earth, and have had frequent recourse to Simms, "On Practical Tunnelling." My illustrations refer mostly to the Blechingly Tunnel, Eng., although I have made some reference to the Mont Cenis,

Hoosac, and the Beacon Street Tunnels; the latter of which is now in process of construction at Newton Centre, Mass., for the Boston Water Works. I regret to say that I was unable to obtain as much information in regard to Machine Drills as I could have wished.

Brookline Water Works. Abstract by the author, Edward A. Handy.

The subject of my thesis is the "Brookline Water Works." I first gave a short history of some of the methods which were proposed to supply Brookline with pure water, and stated as clearly as I could the reasons which led the Commissioners to adopt the present system, rather than any of the others. The works, as now built, consist essentially of a filtering-gallery on Cow Island, in the Charles River, a short distance below the town of Dedham, a pumping-station situated on the edge of the marsh about 3000 feet distant from the gallery, a stand-pipe 14′ in depth on Walnut Hill in Brookline, and a reservoir, with a capacity of 6,500,000 gallons, situated on Fisher's Hill.

I gave a description of each of these essential features and spoke of the various difficulties that were met with in their construction. In speaking of the filtering-gallery, I entered upon the interesting questions which arose concerning the probable source from which the water is derived, and mentioned the various experiments by which it was proved almost conclusively that the water is supplied by springs and does not come from the river at all. The drawings which accompanied my thesis, were of details of such parts of the work as would serve to make my descriptions more easily understood. I did not touch at all upon the question of town distribution, as that in itself would have given material enough for an entire thesis.

The Holly versus the Reservoir System of Water Works. By Clarence L. Howes.

(Abstract not received.)

The Holyoke Dam. Abstract by the author, William F. Huntington.

The site chosen for the dam at Holyoke seems to possess all the advantages that could be desired. There is an available fall of upwards of sixty feet; the bed of the river at the place where the dam has been built is composed of Connecticut River sandstone, which furnishes an excellent foundation for the dam; and the lay of the land below the dam is peculiarly adapted for the construction of canals and mills.

The attention of capitalists was early turned towards the immense water power afforded by the Connecticut River at Hadley Falls. In 1847 a stock company was organized. The following year this company proceeded to build a dam across the river, a full description of which is given in the thesis. This dam was finished November 19, 1848, and was carried away the same day, before the water had risen as high as its crest. Some of the reasons that were given for the failure of the dam are stated in the thesis. In order to determine whether or not it was capable of resisting the pressure brought to bear upon it, the forces acting at a section six feet in width were calculated. From these calculations it appeared that the principal defect in the construction of the dam, was that the slope of the up stream side was too steep. It is said that the dam gave way by sliding upon its foundations. Had the slope just spoken of been less steep, the line of action of the resultant of the forces acting at a section of the dam would have been more nearly vertical, and it is probable that the dam would not have yielded to the pressure of the water, in the way that it did.

During the year 1849 another dam was erected by the Hadley Falls Company. A description of this dam and of the way in which it was built, is given in the thesis. The forces acting at a section of the dam were calculated, and from these calculations it was shown that the dam was sufficiently strong to resist the pressure of the water brought to bear upon it.

An examination of the dam spoken of last, was made in 1868, and it was found that the rocky bed of the river had been worn away by the continuous fall of the water. In order to protect the foundations from being undermined, an apron was built in front of the dam. This apron consists of a crib-work of logs loaded with stone.

The head gates at Holyoke are shown by drawings, which are fully described in the thesis.

The volume of water flowing in the Connecticut River at Holyoke at ordinary times, is estimated to be 5200 cubic feet per second. The available fall is sixty feet. From these data the water power was calculated to be equal to 35,400 horse power. This power is distributed by means of three canals at different levels, as described in the thesis.

The Lawrence Dam. Abstract by the Author, W. F. Sargent.

The Essex Company, the principal owners of the water power and canals, and the principal owners of the town, have erected the dam and canals. They dispose of the water power to other Companies on certain conditions, which are specified with great care and minuteness on the printed proposals for their sale. They define a "mill power" to be thirty cubic feet of water per second when the head and fall is twenty-five feet, which is to be graduated to a greater or less quantity as the head and fall shall be less or greater than twenty-five feet.

Charles S. Storrow, Esq., was Principal Agent and Chief Engineer. Capt. Charles H. Bigelow was Assistant Engineer, and under the immediate direction of the latter the works of the dam and canal were carried forward to their completion, and in accordance with the original designs.

The excavation for the foundation of the dam was commenced August 1st, 1845. The first stone was laid Sept. 19th, of the same year, and the dam was completed in 1848. The whole structure is of solid masonry laid in cement. The foun-

dation is imbedded in the solid rock, and bolted to it with iron. The structure is 1,629 feet long, including the wing-walls; the overfall is 900 feet long. The north wing-wall is constructed to unite with guard locks at the head of the canal. The dam is 35 feet thick at the base and 12½ feet thick at the lower end of the coping crest stones. Its greatest height is 40½ feet, and its average height is 32 feet. The water falls from 25 to 27 feet, giving an effective fall of 28 feet for the whole of the river.

The lower front course of stone resting upon the rock is composed entirely of headers, which are let into the rock in such a manner that they cannot slip. All the front courses, and the coping crest stones are of hammered granite. The crest stones are all laid as headers, and each stone is bolted to the stone beneath it. The interior of the dam is composed of common rubble masonry laid in cement. The face has a batter 1 in 12, the crest stones a batter of 1 in 3, and the rear of the dam is laid in steps, having the general slope of 45°. The water is taken from the pond produced by the dam, by an artificial canal, which is about four hundred feet from, and nearly parallel to, the river, and in this space are the sites for the mills. The dam crosses the river obliquely, and is slightly arched up stream.

After giving a general and detailed description of the dam and canals, I calculated the stability of the dam, both with reference to overturning, and to sliding, and under two conditions, first, supposing the water to be just on a level with the top of the dam, second, supposing the water to be ten feet deep on top of the dam, and I found it stable in all cases.

DEPARTMENT OF MECHANICAL ENGINEERING.

On the Coefficient of Expansion of dry saturated Steam in an unjacketed cylinder. Abstract by the author, James H. Head.

Professor Rankine states that the coefficient of expansion of dry saturated steam in an unjacketed cylinder is $-\frac{10}{9}$, and in a jacketed cylinder $-\frac{17}{16}$. That is $p \propto b^{-\frac{10}{9}}$ and $p \propto v^{-\frac{17}{16}}$ when p represents the absolute pressure and v the volume of the steam. These values of the coefficient were determined by calculations which were based on theoretical deductions from the known nature of steam and work. But they were not determined by direct experiment.

The purpose of this investigation was to ascertain whether the values calculated by Rankine, agreed with the results of direct experiment with ordinary steam in ordinary engines, for it was believed that the effect of an important influence was overlooked by Rankine in his calculations.

Twenty-five or thirty sets of indicator cards taken from different engines having unjacketed cylinders, were obtained for examination.

Generally saturated but sometimes superheated steam was used. No data was obtained from jacketed cylinders. The method which was used to obtain the coefficient from the indicator diagrams, was the general one devised by Professor E. C. Pickering, for the establishment of any physical law. A paper detailing the method was read by him at the meeting of the American Academy of Arts and Sciences, held May 12, 1874, and afterwards published by that Society.

As far as this investigation goes, it appears to be true that the coefficient of expansion given by Rankine for unjacketed cylinders is incorrect for practical usage. For,

First, The law expressing the relation of pressure to volume when either saturated or superheated steam is expanding in an ordinary unjacketed steam cylinder is not necessarily of the form $p \propto v^x$. Only in the case of one or two expansion curves

could the relation be expressed by that form, and approximate closely to the truth.

Second, On expressing the relation approximately by the form $p \propto v^x$, I find that the coefficient x is not constant, but that it varies in different engines, and even in the same engine if the point of cut-off be changed.

In the cases which I examined I found it to vary from —.65625 to —1.0200. These extreme coefficients were both derived from saturated steam diagrams taken from the front end of the Harris-Corliss Engine in the Mechanical Laboratory of the Massachusetts Institute of Technology. Its cylinder is 8.01″ in diameter and its stroke 24″. The coefficient — .65625, was derived from diagrams taken with an apparent cut-off of $\frac{1}{18}$. The steam pressure was 71 pounds per sq. in. The speed of the engine was 57 revs. per minute. The coefficient — 1.0200 was derived from diagrams taken with a real cut-off of about $\frac{3}{4}$. The steam pressure was 70 pounds per sq. in. The speed of the engine was about 59 revs. per minute.

NOTE. — The author, in closing his thesis, expressed the hope that he should be able to carry this investigation further; but his sudden death on Aug. 18th, closed this and all his other earthly labors, and ended a life of great nobleness of character and bright promise.

The Construction of Gear Teeth. Abstract by the author, Thomas Hibbard.

I have not attempted to consider, in this thesis, all the bearings and details of the subject of designing teeth, but have called attention to some of the most important points, and have discussed a few of the principal methods by which teeth are constructed at the present day.

After a few introductory remarks, in regard to the construction of teeth in the past time, I have given some of the reasons for the selection of the proper curves for teeth, and have distinguished between the two great classes: — viz., involute teeth, and epicycloidal teeth. It is the latter class which is

principally discussed in this thesis. A few of the merits and demerits of involute teeth are spoken of.

Attention is then called to the fact that there are many ways of approximating to the true epicycloidal curve, some of which have very little effect on the true action of teeth, while others are exceedingly detrimental. The use of the describing circle in drawing flanks and faces to work together is explained. Then follows an explanation of the method of drawing rolled curves, and consequently curves for teeth, by means of normals, when no describing circle is used. In connection with this, I have added one or two problems which arise out of a consideration of this method, such as: — to find the path of contact; to find meeting points in the parts which work together; to draw clearing curves, etc. I illustrated this method with its problems with parallel flanked teeth on gears of 12 and 10 inches radii.

The importance of selecting the proper describing circle, if constructing teeth by the correct method, is next discussed. Among others, these four important elements depend on the size of the describing circle: — 1st, The number of teeth in gear at any one time, and consequently the force that can be transmitted by them. 2d, The thickness of the teeth at the base, and, hence, their strength. 3d, The extent of wearing surface on the flanks and faces of the teeth, and, therefore, the durability of the teeth. 4th, The obliquity of action of the teeth, and the friction produced thereby on the bearings of shafts. The influence of the size of the describing circle upon each of these elements is discussed.

In order to clearly point out the peculiarities and differences of the various methods of designing teeth now in common use, I have drawn the outlines of two teeth of large dimensions by each method discussed. For convenience of comparison I have traced them on separate sheets, so that they can be superposed on each other, and most easily present to the eye the various points of difference.

I have discussed the: — (*a.*) Parallel flanked teeth; (*b.*) Willis' Odontograph teeth; (*c.*) Rankine's approximate method; (*d.*) Haswell's approximate method; (*e.*) Radial flanked teeth; (*f.*) Molesworth's approximate method; (*g.*) Hussey's method; and (*h.*) the correct method of finding a series of circular arcs to which the true curve is tangent.

To compare with Willis' and Rankine's, I have drawn the same teeth by the correct method (*h.*), using the same describing circles which were used in those methods. The approximation of those methods is thus made clearly evident. With each plate I have endeavored to point out the chief peculiarities, and advantages and disadvantages as regards correctness of form, correctness of action, strength of teeth, obliquity of action, etc.

The length of addendum is then treated of, and its influence on the action of teeth. Rules for the selection of the proper addendum to give required results, are presented, together with a short discussion on the length of the arc of action most suitable for general cases. Willis' rules for addendum are given, and by them is calculated a short table for the length of addendum which would be given to certain gears, providing the arc of action was 1.4 times the pitch. The sizes of gears were selected from the pattern list of the Lowell Machine Shop. The variation in length of addendum with the number of teeth is proved by this table.

In closing, there are a few remarks about the selection of a proper method of designing teeth, which selection depends on the judgment of the designer and his knowledge of what has been done, whether that knowledge is derived from a study of good books, the opinions of practical men, or his own experience.

The Crank as a means of converting Reciprocal into Circular Motion. Abstract by the author, J. Austin Knapp.

This thesis begins with an historical account of the use of the crank as a means of converting reciprocating into circular mo-

tion, and of the erroneous opinions which mechanicians have from time to time held regarding some of the more subtile forces developed during its action. The tendency to avoid the crank engine by the invention of rotary engines is referred to, and the theories of Mr. Charles I. Porter, of the Allen Engine Co., are then discussed.

Most of the mathematics of the thesis was given to Mechanical Engineering students of the Institute, by Professor Channing Whitaker, during the sessions of 1873–74 and 1874–75.

The principal points discussed in the thesis, show how to find the following things: —

(*a*) The crank pin position from that of the piston.

(*b*) The piston position from that of the crank pin.

(*c*) The velocity ratio and the actual velocity of the piston and crank pin, at any point of the stroke.

(*d*) The rate of acceleration or retardation of the piston at any point of the stroke.

(*e*) The force producing acceleration or retardation at any point of the stroke.

(*f*) The relative pressures acting on the piston along the connecting rod, perpendicular to the guides, perpendicular to the crank arm and along the crank arm.

The work is illustrated by numerous diagrams representing the positions, velocities, rates of acceleration, forces and pressures before referred to, and also showing the effect of short cut-off and of heavy reciprocating parts as modifiers of these pressures.

Several of the formulæ are applied to the case of an Allen Engine having a cylinder 16″ diam., with 30″ stroke, and making 120 revs. pr. m. The reciprocating parts of this engine weigh 1200 lbs.

Governors. Abstract by the author, Wilfred Lewis.

The purpose of the governor is to maintain the prime mover to which it belongs at a constant uniform speed. The object of

the present thesis is to show how far, theoretically, it is possible for a governor to accomplish this purpose. Accordingly, the principles upon which the various governors considered, depend for their action have been discussed. No special classification has been followed, but according to that given by Rankine, the governors contained in this thesis might all be comprised under the head of position governors, which might again be divided into those which are in principle either approximate or isochronous.

The common pendulum governor, originally invented by Watt, appears to have been the first form used on the steam engine. Beginning with this, its operation is, in the first place, considered independent of friction and resistances to be overcome by the collar, and then the effect of such resistances upon the speed of the engine is shown, and a formula deduced by which the proper weight for the balls may be calculated when these resistances are known, and any desired degree of sensitiveness assumed. This governor can in no case be perfectly isochronous, but there are several ingenious varieties, among which are mentioned the loaded pendulum governor, Porter's governor, and one or two peculiar devices for communicating the motion of the balls to the collar.

Under the subdivision of "isochronous governors" a description is taken from Rankine of his "Isochronous Gravity" governor and the parabolic pendulum governor.

Waters' spring governor and the Huntoon governor are also classed under the same division, and the principles discussed upon which their good qualities depend. As generally constructed, however, it is shown that in Waters' governor these principles are not perfectly complied with, but are sacrificed for the purpose of allowing the governor to be readily adjusted for different speeds.

The Huntoon governor differs in principle from most of the others, and seems to leave very little room for improvement.

Cylinder Condensation. Abstract by the author, Thomas D. Plympton.

This thesis gives the calculated results of an experiment upon cylinder condensation. The experiment is one of a series, made in the Mechanical Laboratory of the Institute during the winter of 1874–75, for George B. Dixwell, Esq. The pressure of the superheated steam was 70 lbs. per square inch. The temperature of the steam was 590° F. The real cut-off was about $\frac{1}{4}$.

I commence with a description of the apparatus used; and then of the manner of working up the results. I give the record of the most important readings, and the results of some preliminary experiments on the clearance and leakage of the engine. The following is a list of some of the results calculated from this experiment.

(1.) The horse power produced.

(2.) The total heat of the exhaust steam as derived from the calorimeter measurement.

(3.) The weight of water used per horse-power per hour.

(4.) The weight of steam in cylinder per stroke, from the pressure and volume given by the mean card, on the supposition that the steam is saturated.

(5.) The equation of the expansion curve for each end of the cylinder, and the point of cut-off.

(6.) The weight of steam passing through the cylinder per stroke from small tank measurement, which, when corrected for compression and leakage in and out, is the true weight of the steam in the cylinder.

(7.) The pressure at different points of the stroke corresponding to this weight, on the supposition that it is dry, saturated steam.

(8.) The temperature of the steam in the cylinder at different points of the stroke.

(9.) The total heat of the steam in the cylinder at different points of the stroke.

Abstract of Thesis on Steam Pumps. By F. T. Sargent.

A pump is a device for passing a fluid through a tube. An early account of such a contrivance states that Danaus, an Egyptian, assisted by his fifty daughters, dug wells, and by means of pumps supplied the city of Argos with water. This was probably, the first water supplying company ever formed, dating somewhere about 1485 B. C. Some suppose, however, that Ctisibus, who was an Alexandrian, and lived 224 B.C., was the first to invent the pump. The pump was described by Hero, 150 B. C.

Among the first practical applications of steam was that of the Marquis of Worcester for raising water, about 1630. His device is often mentioned as a steam engine; it was, however, a steam pump, as will be seen from his description of it, in his century of inventions. But Worcester's pump was not used to any great extent.

In 1699, Capt. Thomas Savery improved on Worcester's pump, by combining with it a contrivance for producing a vacuum by the condensation of steam. This machine, however, would not raise water more than sixty feet. Newcomen improved on Savery's machine, and in 1714 built his first pumping engine. It could be placed on the surface near the mouth of the mine. Those previously used were placed in the shaft, one above the other, perhaps fifty feet apart. In 1720, Beighton applied the hand gearing. In 1775, Smeaton built a pumping engine having the parts so much better proportioned than those preceding it, that he increased the duty of the pump 50 per cent. Watt appeared about this time, 1776, with his pumping engine, making it a new machine, and in 1785 he had greatly perfected it. Engines are built, at the present time, having the same general features as Watt's engine of 1785.

But steam pumps were not to be limited to the mere draining of mines. They are now used for almost every imaginable purpose. Their demand has not exceeded the supply, if one

may judge from the vast number and variety manufactured. If we believe the makers, we shall conclude that each one in turn is "the best steam pump in the market." It is not my purpose to describe all the different styles and kinds, (this would be impossible,) but simply to give a short description of a few of the prominent ones.

After a short, general description of the manner in which steam pumps work, I have given more in detail a description of the contrivances for changing the motion of the valves at the ends of each stroke, and of any other peculiarities in the construction or the working of these pumps, that I have been able to discover.

In the case of several pumps that are said to have no dead point, I have been able, without much difficulty, to stop them so that they would not start again unless I helped them. Some steam pumps, on account of their long, and too slender piston rod, are liable to tremble considerably, when pumping against very much resistance. Where the resistance is great and where room is to be economized I should prefer one of the class in which the water and steam cylinders can be placed quite near to each other.

The numerous small steam passages of various steam pumps are objectionable, as they are liable to become choked with grease and dirt.

All the working parts of some of these pumps are inside of the body of the machine. They are well adapted for service in exposed and dusty places.

Among the pumps discussed are the Knowles,— Earle,— Blake,— Niagara,— Dayton,— Wright,— Eickemeyer,— Cameron,— Cope and Maxwell,— the Pulsometer, which is very much like a modification of Savery's pumps, — the Cornish pumping engine, the Leavitt pumping engine, and the Worthington Duplex pumping engine. The duty given by the Leavitt engine appears to be "the highest that has ever been obtained, by trial test, of any pumping engine in this country,"

the duty being 103,923,215 ft. lbs. per. hundred lbs. of coal consumed. Sixty or seventy Worthington engines are said to be used at the present time; the duty is comparatively low, but the cost is correspondingly small.

Locomotives. An abstract by the author, J. B. Stanwood.

After giving a short historical sketch of the locomotive, the thesis divides into five distinct parts, which are enumerated and discussed as follows: —

1st. The description and the various uses of the locomotive. Locomotives are used for three distinct purposes, (*a*) for transporting passengers, (*b*) for transporting freight, (*c*) for switching or shunting cars at terminal points, thus arranging these cars into trains for the use of passenger and freight service. The engines for these separate duties have to be constructed differently, as the requirements of each demand; these differences are stated, together with the reasons for them. A brief mention is made of Fairlie's and Meyer's locomotives and of engines used on heavy grades.

2d. Resistance and Traction. It requires work to move cars, on account of the resistance due to the friction at the rails and in the running gear, and the resistance offered by the atmosphere. The rule given by Mr. D. K. Clark (an English engineer) for calculating this resistance, is compared with a table given by Mr. M. N. Forney (an American engineer). The latter is preferred as it more nearly coincides with American practice.

Under the head of *Traction*, it is found that the power of the locomotive is proportional to its weight, within limits. The horse-power is deduced in two ways: one, by simply multiplying the resistance of the train in pounds, by the space passed over, in feet per minute. The product divided by 33,000 will be the horse power. The second way takes into account the size of the drivers, the piston pressure per square inch, and the diameter of the piston or cylinder.

3d. The Combustion of Fuel and the Evaporation of Water. Under this head are considered the values of anthracite, Cumberland (semi-bituminous) and bituminous coals for steam purposes, the results being deduced from a report by Professor W. R. Johnson to the Navy Department, upon American Coals. The advantage obtained by heating the feed-water before it enters the boiler, is discussed, and the amount, in dollars, that would be saved if the water were heated to 150° F., without any additional outlay for fuel, is calculated. This amounts to about $80,000 for 225 locomotives for the space of one year. The Magoon Feed Water Heater is described and a figure of it given.

4th. The Boiler. Under this head, the proportions between heating and grate surface are given, Mr. D. K. Clark being taken as authority. The thickness of shell and the kinds of material used for its construction are stated, together with various methods used by builders in constructing them. The means of obtaining steam room by the use of domes and "wagon-top" boilers is described, together with a rule for the proper clearance for tubes, etc.

5th. The Cylinder. There are four important periods during one complete stroke of the piston. They are the periods of *Admission*, *Expansion*, *Exhaust* and *Compression* of the steam. Each is briefly discussed.

The efficiency of the locomotive G. Twichell, on the Boston & Albany Railroad, is deduced by comparing the amount of work which the coal that it consumes, is capable of doing, with the actual amount of work which the engine does. The result is satisfactory.

DEPARTMENT OF MINING ENGINEERING.

An Article on Salt. By Moses D. Burnet. (Abstract.)

A short introduction is given. The subject is then treated under the following heads: —

1st. What constitutes a good salt.

2d. A short description of the salt manufacture, with a discussion of the properties taken advantage of, and the processes used to obtain purity in salt.

3d. Efficiency of pumping processes, as shown by analyses.

4th. Analyses of foreign and domestic salts, showing their comparative merits.

The Stamps of Lake Superior compared. By C. W. Goodale. (Abstract.)

In this thesis the author has striven to compare the different kinds of stamps from a theoretical point of view. He has calculated the mechanical power exerted per square inch of shoe surface of the stamp. A considerable amount of data has been collected, and a careful description given of the working of the three principal varieties of stamps, namely — the Ball steam stamp, the atmospheric stamp, and the fall or pestle stamp.

Report on Burleigh Tunnel Ore, Colorado. Abstract by B. A. Oxnard.

The ore which was given me to work up is one which comes from one of the veins discovered in running the Burleigh tunnel through the mountain, near Georgetown, Colorado. This enterprise, started by Eastern capitalists, was under the direction of Mr. Charles Burleigh, the inventor of the steam drill of the same name. These drills were exclusively used in the boring of the tunnel. At Georgetown were worked a number

of rich silver mines in this very mountain, and the tunnel was pierced with the double intention of, 1st, Discovering, if possible, new lodes; (as before stated, it was from one of this latter kind of lodes, the ore under consideration came). 2d, Ventilating, draining and otherwise, assisting in the working of the then existing mines.

The sample given me was supposed to be a fair one, indicating the relation between the mineral part and the gangue in the ore, also showing the average richness of the mineral part. It came to me in lumps and powder. The examination was begun by making a search for the minerals contained in it. The greater part was galena and zinc blende, in noticeable quantities, iron pyrites and some copper pyrites. The gangue was mostly siliceous, with little specks of mica here and there, and some feldspar and clay. There was also observed a little decomposed siderite, but not enough to give any trace of CO, in the analysis of the ore.

The work assigned to me was the extraction of the lead and silver from the galena, and that of the silver from the zinc blende. The blende for this did not have to be reduced to the metallic state. The weight of the ore sample was 214 lbs. 12 oz. I went all over this lot, breaking it into small pieces and putting aside a specimen of all the different minerals found, for blowpipe analysis. Their names have been given above. Another object of the picking and breaking up of the ore, was to sort out as much as possible of the galena which was free from blende, as this would save the trouble of separating it by jigging. The ore was thus divided into two lots, one consisting of pure hand-picked galena, the other, of mixed galena, blende, gangue, etc.

These lots by weight then were: —

Blende, galena, etc., portion	176 lbs. 6 oz.
Galena (hand picked)	33 " 6 "
Samples of minerals	4 " 4 "
	214 lbs. 0 oz.

Each portion of the ore was then crushed, first in a Blake crusher, and then between rolls, the galena to $\frac{1}{40}$ in., the blende-galena to $\frac{1}{4}$ in. After crushing, the portions weighed: —

Blende-galena portion	176 lbs. 8 oz.
Galena (hand picked)	33 " 2 "
	209 lbs. 10 oz.

I explain the increase in weight of the galena-blende, by the fact that the galena being crushed first, some of the dust was not removed, but was taken up after with the blende-galena. After the crushing, each part was well mixed, and a sample was taken from each, of which a complete analysis was made.

The two samples being analyzed, first qualitatively and then quantitatively, were found to contain: —

ANALYSIS OF BLENDE-GALENA PART.

Lead	36.00 per cent.
Zinc	7.84 "
Iron	9.81 "
Copper	0.33 "
Sulphur	21.22 "
Silver	0.06 "
Gangue	16.43 "
Water	0.75 "
Undetermined	5.56 "
Total	100.00 per cent.

ANALYSIS OF GALENA PART.

Lead	73.60 per cent.
Zinc	0.45 "
Iron	4.19 "
Copper	0.39 "
Sulphur	16.33 "
Silver	0.128 "
Gangue	2.62 "
Water	0.35 "
Undetermined	1.942 "
Total	100.00 per cent.

The ore after sampling weighed: —

Blende-galena portion	171 lbs. 0 oz.
Sample ditto	5 " 2 "
Galena portion	31 " 6 "
Sample ditto	0 " 10 "
Total	208 lbs. 2 oz.
Dust lost in blende galena portion	0 lbs. 6 oz.
Dust lost in galena portion	1 " 2 "

The galena portion was now all ready to roast, having been picked so as to require no ore-dressing. It was therefore put aside for the time. The blende portion had to be dressed, so as to separate the galena, blende and gangue, from each other. The specific gravity of the two minerals differing very greatly, that of galena being from 7.25 to 7.70, and that of blende from 3.5 to 4.0, a very good separation could be effected by jigging.

As a preliminary step, the ore was separated by sieves into five sizes, viz.: —

1st size, that which remained on $\frac{1}{4}$ in. mesh.
2d size, that which passed $\frac{1}{4}$ in., but remained on $\frac{1}{8}$ in.
3d size, " " $\frac{1}{8}$ in., " " $\frac{1}{20}$ in.
4th size, " " $\frac{1}{20}$ in., " " $\frac{1}{40}$ in.
3th size, " " $\frac{1}{40}$ in.

The first three sizes were put each separately on the jig. In this case the operation was made easier by the iron pyrites in the ores, which being intermediate in specific gravity between galena and blende, formed a bright thin layer between the other two minerals. It was of great importance that as little blende as possible should be mixed with the galena, as it would be in the way in the future work, but it did not make as much difference whether the blende was mixed with a little galena or not. The iron pyrites did not harm either part. The coûrse I followed was this: After having skimmed off the gangue I skimmed off the blende and the layer of pyrites, leaving only the galena. Some of the galena was taken with the blende to make sure that no blende remained in the galena. This accounts for the rather high percentage of lead found in the blende part. The ore was put in so as to be about

three inches deep for the larger sizes, and about two inches for the smaller. I gave about one hundred strokes for each portion, and the separation appeared good in each case. The jig was a $\frac{1}{30}$ in. sieve placed in a large tub of water, and suspended to a spring board above. A good deal of ore which had not passed in the dry sifting went through the $\frac{1}{30}$ in. sieve. This was collected and treated on the shaking table, as was also the $\frac{1}{40}$ in. product and that which had passed the $\frac{1}{40}$ in. sieve. The principle of separation in the shaking table is to throw the ore up an inclined plane by means of a jerk at regular intervals, while water, between the jerks, causes it to go down. By regulating the stream and the slope of the table, the water may be made to carry off the blende and gangue, leaving the galena on the jerking table.

There were three parts from the jig, viz.: — galena, blende, and gangue portions. The gangue portion having been jigged several times to get all the mineral part out, was then put aside and not worked any more. The ore from the shaking table was also divided into three parts, viz.: — a galena portion, a mixture of gangue and blende, and a slime which was not worked.

The weights from the jig were: —

Gangue portion	20 lbs. 7 oz.
Blende portion	48 " 0 "
Galena portion	63 " 6 "
	131 lbs. 13 oz.

The weights from the shaking table were: —

Slime	2 lbs. 14 oz.
Blende and gangue portion	13 " 0 "
Galena	29 " 4 "
	45 lbs. 2 oz.

Samples were taken of the three portions from the jigs and two portions from the shaking table, and they were analysed for lead and zinc, and assayed for silver, with the following results: —

GALENA FROM JIG.

Lead	70.36 per cent.
Zinc	0.75 "
Silver	0.103 "

ZINC BLENDE FROM JIG.

Lead	14.27	per cent.
Zinc	20.75	"
Silver	0.035	"

GANGUE FROM JIG.

Lead	6.28	per cent.
Zinc	0.88	"
Silver.	0.013	"

GALENA FROM SHAKING TABLE.

Lead	62.65	per cent.
Zinc	1.90	"
Silver	0.087	"

RLENDE AND GANGUE FROM SHAKING TABLE.

Lead	14.15	per cent.
Zinc	10.89	"
Silver.	0.035	"

The galena had now been separated from the rest of the ore and after drying and crushing to $\frac{1}{40}$ in., the different parts weighed: —

Galena hand picked	31 lbs. 6 oz.
" from jig	63 " 6 "
" from shaking table	29 " 4 "
Total Galena	124 lbs. 0 oz.

An analysis of this gave: —

Lead	69.35	per cent.
Silver	0.106	"

(The per cent. in this case were calculated from the aliquot parts.)

This galena was roasted in a reverberatory furnace at a heat just below the fusing point of galena. The object of the roasting is to drive off the sulphur and this would be retarded by the caking of the galena. The ore is stirred constantly to expose every part of the ore. In this case, I failed to avoid caking by fusion, but the lumps thus formed were broken up as much as possible by the stirrer. The roasting went on for three and one-half hours, at the end of which time no more sulphur came off from the ore. A sample was taken at the end of two hours' roasting, also at the end of the roast, and they were analyzed for sulphur with the following results: —

Sulphur after 2 hours roast	8.61	per cent.
" " 3½ "	8.15	"
Before roasting, the hand picked galena contained	16.33	"

The roasted galena was then analyzed with the following results: —

Lead	59.28 per cent.
Silver	0.11 "
Weight roasted Galena	113 lbs. 11 oz.

The great loss of lead was in the lead fumes which went up the chimney during the roasting. The theoretical amount of lead to be got from the roasted ore was then 67 lbs. 6 oz., and the silver 0.125 lbs.

A flux was calculated for the roasted galena according to the percentage of sulphur and lead in it, which consisted of 52.4 lbs. magnetite and 4.9 lbs. charcoal dust, to 100 lbs. of ore. 60 lbs. of ore were mixed with the fluxes in the above proportions; but, one charge of ore of 15 lbs. having been tried, it was found by its action on the crucible, that there was too much iron for the amount of coal, and consequently 4 lbs. charcoal dust were added to the remaining 45 lbs. The result proved more satisfactory. The iron is put in to reduce the sulphide of lead to lead and to take up the siliceous impurities. The charcoal reduces the oxides of lead and iron that are formed. When the 45 lbs. ore gave out, each charge of 15 lbs. of ore was mixed with 2 lbs. charcoal and two thirds as much magnetite in proportion, as before. The estimate of magnetite was at first too large on account of an error in the estimation of the per cent. of sulphur in the roasted ore, which was caused by an impurity in one of the laboratory reagents.

The number of charges fused was 8, out of which, one charge went through the crucible and about 4 lbs. of metallic lead were lost. 7 of the 8 charges had 15 lbs. ore, and the 8th had 8 lbs. 10 ozs. The charges were smelted by being first well mixed with the fluxes, and then put into a black lead crucible and fused at a bright red heat from two to three hours until the whole mass was perfectly liquid. The charge was then poured into a mould. Great care had to be taken to heat the black lead crucible very gradually, as they are liable to crack if this is not done.

The result of the smelting consisted of the slag, matt and

51 lbs. 6 oz. crude lead. If the 4 lbs. lost by poor crucible were added to this it would give: —

Total lead obtained (about)	55 lbs. 6 oz.
Theoretical amount of lead in ore	67 " 6 "
Loss in slag and matt	12 lbs. 0 oz.

This would show that between 17 and 18 per cent. of the lead had gone into the slag, matt and fume.

The crude lead was refined by fusing it, to drive off the sulphur, and by sweating it. This gave 47 lbs. 14 ozs. of refined lead, which was assayed for silver with the following result: —

Per cent. silver obtained in lead . . .	0.21
Weight silver	0.101 lbs.
Loss on theoretical amount	18 to 19 per cent.

The lead was melted in a cast iron pot and heated to driving. 2 lbs. 6 oz. of zinc (5 per cent. of the amount of lead) were melted in a black lead crucible, and just as oxide of zinc was beginning to be formed and to burn, it was poured into the molten lead and the bath having been thoroughly stirred, the zinced lead was poured into ingots. The process of extracting silver out of lead, by means of zinc, is called "Parke's process" after the name of its inventor. It depends on the fact that when zinc and silver lead are mixed at a strong red heat nearly all the silver goes with the zinc.

It consists of 5 stages. 1st, Zincing the lead. 2d, Sweating off the pure lead from the argentiferous zinc lead, owing to the lower fusing point of pure lead. 3d, Refining the lead, thus obtained. 4th, Removing the zinc from the argentiferous zinc lead by distillation. 5th, Cupelling the argentiferous lead. The first stage I have already described. The ingots were then put on the sweating furnace, and the pure lead melted from the zinced lead. The lead thus melted was refined by driving off the zinc, and it was then assayed for silver, giving 0.0038 per cent. Ag. Before refining, the weight of the lead was 38 lbs. After refining, it was 34 lbs. 5 oz. The loss was due to the escape of lead fumes as well as to the driving off of the zinc. The argentiferous zinc lead was then refined by distilling off the zinc at a bright red heat in a black lead crucible.

Charcoal was put on top of the molten liquid to reduce the litharge formed while the oxide of zinc burned off. The time taken to distil the zinc was two hours. The argentiferous lead was then poured into ingots and weighed 9 lbs. 1 oz. A sample of this was taken and assayed 0.855 per cent. Ag. The argentiferous lead was then cupelled in a cupel furnace. The furnace was first heated to a bright redness and the ingots of lead were put in one by one, and as they oxidized, the litharge was poured off. The ingots were put in 3 hours 30 minutes after the fire was started, and the button blicked 2 hours 23 minutes after the lead had been put in. The silver button weighed 22.7782 grs. or .0502 lbs. instead of the theoretical .0782 lbs. which had been put on the cupel.

The cupel was made by mixing 15 lbs. of bone ash, 2 oz. fire clay and 6 oz. litharge.

		Per cent. Ag.	Wt. Ag in lbs.	Loss Ag since last operation.	Per cent. Pb.	Weight Pb.	Loss Pb since last operation
124 lbs.	Galena	0.106	.1314		69.35	86 lbs.	
113 lbs. 11 oz.	Roasted Galena	0.11	.1252	.0062	57.28	67 lbs. 6 oz.	18 lbs. 10 oz.
51 lbs. 6 oz.	Crude lead	—	—	—	100.0	51 lbs. 6 oz.	16 lbs. 0 oz.
4 lbs.	Loss by accident	—	—	—			
47 lbs. 14 oz.	Refined lead	0.21	.1005	.0247	99.8	47 lbs. 14 oz.	3 lbs. 8 oz.
9 lbs. 1 oz.	Argentif. lead	0.815	.0782	.0796	99.2	9 lbs. 1 oz.	43 lbs 6 oz. 4 lbs. 8 oz.
				.0210			
34 lbs. 5 oz.	Comm'l (refined)	0.0038	.0013		100.0	34 lbs. 5 oz.	
0502 lbs.	Silver button	100.0	.0502	.0293	.0	0	9 lbs. 1 oz.

	Lead obtained.		34 lbs. 5 oz
	Silver obtained	.0502	Total lead in ore, 86 lbs. 0 oz.
		.1314	total silver in ore.

		Loss of lead.	Loss of silver.
Silver in the ore	0.1314 lbs.		
Lead in the ore	86 " 0 oz.		
Loss from roasting		18 lbs. 10 oz.	0.0062 lbs.
Loss from smelting		12 " 0 "	
Loss by accident		4 " 0 "	0.0247 "
Loss from refining		3 " 8 "	
Loss from zincing, Sweating and distilling, Loss from refining lead, with silver taken out		4 " 8 "	0.0223 "
Loss from cupelling		9 " 1 "	0.0280 "
Lead obtained		34 " 5 "	
Silver obtained			0.0502 "

The zinc portion was carefully worked, roasted, ground with salt, and re-roasted and amalgamated, but owing to an accident at the last moment the yield of silver was greatly reduced. In the place of .021 of a lb. of silver which the ore contained, only .003 were extracted.

Working of an ore of Silver and Lead from Newbury, Mass.
Abstract by Wm. H. Shockley.

This thesis describes the situation of Newbury, the story of the discovery of the mine, a mention of the gneiss rocks in which it is found, and quotations of analyses of the vein stone. The ore that was worked was float ore from the Chipman Lode. The ore presented the usual appearance of a float ore being covered with oxide of iron and various decomposed minerals. An examination was made of the mineral species, and the following were detected. Galenite, quartz, siderite, limonite, hematite, pyrite, chalcopyrite, tetrahedrite, malachite, azurite, zinc blende, crocoisite, kaolin. The principal mineral constituents are galena, quartz and pyrite.

A partial analysis of the ore gave: —

		Calculated Minerals.		
		No. 1.		*No.* 2.
Silica	16.18	Quartz,	13.61	13.61
Lead	45.39	Sphalerite,	1.21	1.05
Copper	1.33	Chalcopyrite,	3.84	1.65
Zinc	.81	Pyrite,	14.81	15.31
Iron	8.34	Kaolin,	5.17	5.17
Alumina	2.23	Siderite,	.53	.53
Sulphur	16.70	Galenite,	52.68	52.55
Carbonic acid	.20	Limonite,	5.10	5.72
Ferric oxide	5.10		96.95	Tetrahedrite, 2.15
Silver	.20			97.74
Gold	.002			
Undetermined (As, etc.),	3.52			
	100.00			

No. 1 is calculated directly from the ore analysis. Now if we assume the galena to have 19 per cent. Ag. (and this assumption is warranted by the assays) we shall have the galena in the ore (52.41 per cent.) taking 10 per cent. of the silver,

and if the remainder be assumed to constitute the 4.65 per cent. of the tetrahedrite, (which the assay shows to be the case) we shall have the basis for the result given in the second column.

The value of a ton of this in currency is (gold, 1.15) : —

907 lbs lead,	$54.46
58.32 oz. silver,	86.81
.58 oz. gold,	13.89
	$154.96

An examination was made of the various qualities of galena to see how the silver was distributed. The results of the assays are : —

	Per cent.	*oz.*	
Coarse galena from 30′ below surface,	.35	102	$131.65
Medium galena from ore,	.09	29.16	37.61
Fine " "	.22	65.90	85.01
Tetrahedrite "	4.65	1357.19	1750.77
" from Chipman Shaft	2.30	670.68	865.17

Other tetrahedrites have varied from $500–$1300.

DETAILS OF WORKING ORE.

Weight = kilogrammes.

The ore was in large lumps weighing from 10 to 30 kilos. The first operation was to break up these lumps and pick out the ore to be worked. At the same time pieces were picked out and examined for the minerals.

The weight of the whole lot was 816.41 kilos., the amount picked out 324.97 kilos., this being as near as possible fair sample of the whole. The ore was passed through a small Blake crusher and then through rollers; these operations were to crush the ore so it might be fit for roasting. The ore was then sampled, passed through a $\frac{1}{2}\frac{1}{0}''$ sieve, the portion remaining on the sieve was rerolled until it was judged to be about $\frac{1}{2}\frac{1}{0}''$. The loss in crushing was .34 kilos., the sample taken out weighed 6.40 kilos., so that the ore now weighed only 311.13; the loss of 7.64 kilos. was due to sifting, rolling, and to the fact that some of the ore was overlooked and remained behind. The ore was divided into eight charges, each of 39 kilos.; it was roasted in two reverberatory furnaces, each charge being roasted four hours. A sample was taken at the end of two hours, and also

when the charge was drawn; these samples were analyzed for sulphur; the results of these analyses will be found farther on.

After the ore was roasted it was put in the larger of the two furnaces and agglomerated. A sample was taken of this agglomerated ore and analyzed so as to furnish data for calculation of slag, etc. The object of agglomerating the ore, was to make it strong enough to stand the pressure of the fuel and fluxes.

The percentage of sulphur before roasting the ore was 16.70 per cent. The following table shows the per cent. of sulphur removed by roasting.

No. of the charge.	*No.* 1.	2.	3.	4.	5.	6.	7.	8.
Sulphur after 2 hours roast'g,	7.36	7.85	6.60	7.09	not deter.	10.13	5.70	9.91
Sulphur after 4 hours roast'g,	4.18	6.23	4.90	4.97	not deter.	4.85	4.36	5.77

The ore after being agglomerated weighed 251.5 kilos.; a sample was taken and a partial analysis made, so that there might be data enough to calculate the amount of fluxes to be used. After these calculations were made, the ore was run in the blast furnace. The details as to the run will be found in the tables on pages 22 to 30 inclusive. A slag from the Revere Copper Works was used to start the furnace with. It was found after running some time that the proportion of flux and ore was too great for the fuel, so the charge was altered by taking only three-fourths the amount of ore and flux to the fuel; after this the furnace worked well.

The calculations were to have a basic slag; the fluxes used were puddle cinder and limestone; the exact composition of the puddle cinder was not known at the time of the calculation, but it was judged that it contained about 20 per cent. SiO_2 to 70 per cent. FeO, and acting on this supposition the following charge was calculated:—

40 lbs. ore.
25 lbs. puddle cinders.
3 lbs. limestone.
3 shovels coke.

This charge was afterwards changed to

30 lbs. ore.
18¾ lbs. puddle cinder.
2½ lbs. limestone.
3 shovels coke.

This change was made in order to bring the layers of fuel nearer together.

The analysis of the puddle cinder afterwards made and of the roasted agglomerated ore are below.

Puddle Cinder.		*Ore.*	
FeO,	70.62	FeO,	17.11
SiO_2,	15.43	SiO_2,	18.47
Al_2O_3	9.42	Al_2O_3	2.57
		S,	3.27

Now this gives in each charge the following amounts: —

	SiO_2	Al_2O_3	CaO	FeO	S
Ore,	7.39	4.03	0	6.84	1.31
Puddle cinder,	3.86	2.45	0	17.65	0
Limestone,	0	0	1.68	0	0

After allowing sufficient iron to remove the sulphur as FeS the calculation of the per cents. of the components in the slag is as follows: —

	SiO_2	Al_2O_3	CaO	FeO	Pb
Calulated Slag	29.56	9.23	4.41	56.77	0
Actual Slag, as obtained,	30.54	9.71	4.66	48.86	2.44

The discrepancy between the calculated slag and the slag actually obtained is due to two causes; viz., the dissolving of silica from the bricks and the charging of the Revere Slag at sundry times during the run. The analysis of the Revere Slag is: —

FeO, 41.86
CaO, 9.96
SiO_2, 37.00
Al_2O_3, 6.21

The furnace was started with Revere Slag, and the first twelve kettles consisted of this and were laid aside. The remaining products were slag and lead, and a small quantity of iron matte. The lead and slag were separated, and gave 220.42 kilos. slag, 82.54 kilos. lead. There was 90.71 kilos.

foul slag, *i. e.*, slag containing too much metallic lead to be thrown away, consisting of nozzles, furnace bottom, and bits of the total slag with adhering lead. This slag was crushed and sifted; the part remaining on the sieve, jigged; the portion going through the jig treated on the Spitz-lütte. The products from these operations were smelted, and 8.16 kilos. of lead obtained; this was put with the cake lead, increasing its weight to 90.70 kilos. From each cake as it was broken up, a piece of pure slag was picked out; these bits were crushed and sampled and an analysis made of the sample. It is to this analysis that I have reference when speaking of slag, page 20. An analysis was also made of the total slag—it gave 290 per cent. Pb, *i. e.*, 6.39 kilos. Now the amount of lead that should have been obtained is 143.95, the amount that was obtained is 90.71 k.; this with the amount in the slag = 97.10 k. or 67.45 per cent., thus showing a loss in the operations of smelting and roasting of 32.55 per cent.

I am not able to state how much of this loss is due to roasting nor how much is due to smelting. The loss is probably caused by fumes, and it must be caused by volatilization, because all the products have been assayed for lead and none has been found, save as stated.

The cake lead was now refined. It was attempted to do this in a crucible by skimming, but this was found impracticable on account of the great impurity of the lead. The lead was, for the foregoing reasons, run into ingots and sweated. The resultant lead, 62.5 kilos. was quite pure and was all ready to be zinced. This lead was assayed for silver and gave .448 per cent. or 280.31 grms Ag.

There was formed during this process of refining, quite an amount of skimming. There was also quite an amount of dross left on the sweating furnace. Both of these compounds contained a large amount of copper. They were smelted and from the smelting was obtained 7.7 kilos. lead, containing .341 per cent. Ag. or 26.26 grammes; and 12.70 kilos. lead with .332 per cent. Ag. or 42.16 grms. The 7.7 kilos. was from the

skimmings, the 12.70 k. from the dross. The loss of lead by this operation was 7.74 kilos.; the loss of silver cannot be told.

The lead obtained from the smelting of the skimmings and dross was very rich in copper; now it was desired to remove the silver from the lead by zincing. Copper is a detriment to this process and therefore it was advisable to remove it (*i. e.*, the copper). The method devised for doing this depends on the greater affinity of sulphur for copper than for lead. If galena and copper are heated in a reducing atmosphere, lead is set free and copper matte (sulphide of copper) is formed. Taking advantage of this fact, the copper was removed from the lead. The maximum amount of copper that could be present, being known, enough galena was added to change this to sulphide, also a sufficient amount of pyrrholine, magnetic pyrites, was added to make a matte of the formula (Cu_2S FeS) and the fusions were made. The results were very good, a matte rich in copper and a lead very free from copper were obtained.

Weight of lead, 15.25 kilos.
" " matte, 5.90 "

The subsequent operations of desilverizing the lead, cupelling to fine silver and recovering the lead from the various products, yielded very unsatisfactory results, owing to defects in the cupel furnace and other apparatus.

Treatmcnt of a Silver Ore from Silver Islet, Wood's Location, Ontario, Canada, Lake Superior. Abstract by the author, H. L. J. Warren.

The ore was of low grade, the assay value being only about $10 to the ton. The silver was present in three modifications, native, sulphuret, and argentiferous galena. In securing a good concentration of the valuable minerals was found the main difficulty in its treatment. These were present in such minute particles, and the gangue was of so refractory a nature, consisting chiefly of calcite with a small amount of heavy spar, which, after the ore was passed through a $\frac{1}{16}$ mesh, were

reduced to a large extent to a fine powder, which so completely enveloped the ore itself when treated on the jig, or bump table, that no satisfactory separation could be made. After a number of fruitless attempts the bump table furnished two products, a slime, and the remainder of the ore. These were then treated by the spitzlütte of Rittenger, which in the end gave quite satisfactory results. The following table shows the final products both those of value and the waste. It explains itself.

Rich concentrated mineral.	*Weight in kilograms.*	*Percent. of silver.*	*Value of silver.*	*Waste products and slimes.*	*Weight in kilograms.*	*Per ct. of silver.*	*Value of silver.*
Original ore	81.5	.0286	$0.93	Original slime	18.6	.013	$0.098
Product A.	.654	.2351	0.061	Spitzlütte slime	5.7	.005	.011
" B.	.065	1.2563	.032	2d bnmp table slime	1.3	.016	.008
" C.	.081	.8751	.628				
" D.	.163	.0935	.006				
" E.	.109	.310	.013	Product H.	8.7	.008	.027
" F.	1.431	.307	.175	" K.	2.8	.007	008
" G.	.617	.164	.040	" M.	3.4	.010	.014
" H.	.051	.473	.009	" P.	4.5	.009	.016
" I.	1.383	.096	.053	" R.	6.2	.011	.027
" J.	.810	.197	.064	" W.	3.8	.019	.029
" K.	.741	.099	.029	" V.	4.9	.017	.025
Total	6.105		0.51	" X.	3.6	020	.029
Totalsmelt'g pro.	6.105	.241	.59	" Z.	3.9	.009	.014
Accounted for	77.8		.91	" D.	4.3	.008	.013
Loss	3.3		.02		71.7		0.319

Working of an Ore from Middletown, Ct., by Wm. R. Webster.

(No abstract furnished.)

DEPARTMENT OF ARCHITECTURE.

Design for the buildings for a City Water Works. Abstract by the author, Amos J. Boyden.

The problem for solution in this thesis required designs for an Engine House and Stand Pipe Tower in the public park of a small city, together with such other buildings, or architectural adornments, as would be conducive to the convenience or pleasure of visitors to the park.

In the design, the plan of the engine house resolves itself into three parts, as follows: —

1st, that part devoted to the government of the works, occupying the front of the building, and two stories in height. The principal rooms on the first floor of this part are, an office with adjoining ante-room, a visitors' room, a commissioners' room and a lavatory. These rooms are ranged along the main entrance hall, from which a stairway leads to the second floor, and to the basement.

On the second floor are five large well lighted rooms and a bath room. This floor is designed for the use of the resident engineer and his family.

2d. Part second of the building consists of the engine room and an adjoining boiler room, the floor of which is four feet lower than that of the engine room. A gallery runs around the engine room, access to which is gained from the first landing of the stairs from main hall to second floor.

3d. Wings one story in height extend from the engine room and from the boiler room to the retaining wall in the hill side, into which they run several feet. The boiler room wing is designed for a coal house, and is so situated that the coal may be dropped from the carts directly into the bins.

The engine house wing is divided into a machine shop and a carpenters' shop.

A chimney shaft 106 feet high is situated near the boiler room, on the axis of the plan.

The water is to be forced a distance of about 600 feet to the stand pipe tower, which is 160 feet high, 24 feet square at the base, and 20 feet square at the top. Adjoining the tower is a small gate house.

The most architectural building in the park is a refreshment hall, containing waiting rooms for ladies and gentlemen, a hall for pleasure parties, and various smaller rooms shown on the accompanying plans. As in the engine house, wings extend to the retaining wall, the flat roofs of which give access to the

hall, while the rooms below may serve as ice house, and cellar, and the well lighted part as kitchen.

The required thickness of the retaining wall, 24 feet high, was calculated and found to be 7.65 feet at the base. The roof trusses of the engine house are large primary trusses, composed of two wooden rafters, connected by an iron tie rod, the rafters being supported by three small secondary trusses. The stresses in the various pieces of one of these trusses have been calculated. The required sectional area of the rafters was found to be 29.06 square inches.

Calculations were also made for the required indicated horse power of the engines.

DEPARTMENT OF CHEMISTRY.

Anthracene Pressings. Abstract by the author, Leonard P. Kinnicutt.

My thesis can be divided into the following principal topics:

1. Historical notice of the discovery of Anthracene.
2. Description of the manufacture of Anthracene.
3. Anthracene Pressings.
4. The partial separation of the Hydro-Carbons, which compose these pressings, into four principal products, by means of the difference of their solubility in alcohol.
5. The determination of Anthracene in the four products, by means of Suck's test.
6. Forming crystals, by treating each of the four products with a solution of picric acid.
7. The finding of Phenanthrene in the pressings.
8. The Phenanthrene colors, and the value of Phenanthrene in the future.
9. The value of a quantitative test for Phenanthrene.
10. Testing the different methods by which it would seem possible to determine Phenanthrene quantitatively.

11. The comparison of the different methods, and the reasons for changing Phenanthrene into Phenanthrene Quinine, for the determination of Phenanthrene in this investigation.

12. The determination of Phenanthrene in the four different products.

13. The general result of my work.

DEPARTMENT OF PHYSICS.

Report of a series of experiments made with a Holtz Machine. Abstract by the author, S. J. Mixter.

1. An account of previous measurements of electrical machines by Moscart and Rossetti.

2. The machine used in my experiments was made by Mr. E. S. Ritchie. It has a single plate 2 feet in diameter. The motor was a small high pressure steam engine, having a cylinder 2 inches in diameter, and 3¼ inches stroke. The work was measured by a form of dynamometer first used by Huyghens; the principle involved is, that the work transmitted through a belt equals the speed of the belt into one-half of the difference in the weights which balance on the two sides of the driven pulley. The strength of the current was measured by a galvanometer made from the secondary coil of a resistance coil, having a resistance of 6,313 ohms, and whose constant was accurately determined.

3. Various series of experiments were made to determine the work converted into electricity.

(*a.*) Amount of work required to run the machine when discharged and charged, varying the length of the spark.

(*b.*) On the absolute strength of this current, and the amount of work converted into electricity. From the results obtained the electromotive force and interior resistance were calculated.

Curves representing the several series of observations are given.

The Empire of Austria. By Wm. A. Prentiss. Abstract.

Area and physical features; Component parts of the Empire; Ethnology; Vegetable and mineral products; Statistics of Commerce; Early history and growth of the Empire; Present constitution and government; Austria since Sadowa; Present position and prospects; List of authorities referred to

Switzerland. By James Liddell Arnott.

(Abstract not received.)

THE DEPARTMENT OF ARCHITECTURE.

The founders of the Institute of Technology included Architecture among the branches first to be provided for, and a professorship in this department was established and the chair filled on the opening of the school in 1865. This appointment was made and accepted, however, on the understanding that the work of instruction should not be begun until proper apparatus had been collected, and opportunity given for studying the methods of professional instruction employed in architectural schools abroad. In the spring of 1866, accordingly, Professor Ware asked leave of absence and remained abroad until the end of the following year, examining the foreign schools, consulting personally with the architects in charge of them or with others who were familiar with their working, and collecting casts, photographs, drawings and other materials of instruction, which the generosity of some friends of this undertaking had given him the means of purchasing.

THE ARCHITECTURAL MUSEUM.

The collections thus begun have gradually increased in amount and value until they will compare for interest and for serviceableness with those anywhere put at the disposition of architectural students, supplemented as they are by the collections of the Museum of Fine Arts, established in the immediate

neighborhood, and by the treasures of the Boston Public Library, whose trustees, as well as those of the Boston Athenæum, have done everything in their power to increase the facilities for their use. Some unusually favorable circumstances rendered these collections, even at the outset, much more extensive and valuable than was reasonably to be looked for, especially in respect of mediæval sculpture and carvings, and architectural drawings. A large and almost unique collection of casts from Lincoln and Southwell minsters, fortunately fell into our hands, which was afterwards supplemented by considerable additions from French Gothic work of the same period. To the generosity of the late Mr. Ernst Benzon, formerly a merchant of Boston, we were indebted for an unusually good collection of school drawings, made by students in architecture at the École des Beaux-Arts in Paris, and at the French Academy in Rome. These have been added to, as circumstances have favored, until we now have a series of works, illustrating every stage of study, which for completeness and extent, as well as for intrinsic merit and usefulness as examples to the student, is hardly to be found elsewhere, even in the ateliers of the École des Beaux-Arts itself. These collections were largely augmented by the kindness of many gentlemen, mostly architects, who, both in England and on the Continent, as well as on this side the water, evinced a kindly interest in our undertakings and gave not only photographs of their works, but tracings and lithographic copies of working drawings, with specimens of specifications, estimates, bills of quantities, and various forms of business papers. We are under special obligations to Mr. Waterhouse, Mr. Withers, Mr. Norton, Mr. Nash, Mr. Rickman, Mr. Keeling, Mr. Edis and the late Mr. Papworth, in London, to Mr. Bryce in Edinburgh, and the late Mr. Thomson in Glasgow, and to M. Viollet-le-Duc, M. Charles Garnier and M. Lesoufachér in Paris. M. César Daly, a constant friend of this country, presented to the department his valuable work illustrating the domestic architecture of the Second Empire, and the French Minister of Public Instruction,

M. Duruy, acting through our minister, General Dix, put at our disposition a number of illustrated works relating to the architectural history of France, among which are the magnificent monograph of the Cathedral of Chartres, and the two volumes entitled the "Statisque Monumentale de Paris." The Institute of Scottish Architects, and the Architectural Publication Society of London, added a number of valuable publications, while the Royal Institute of British Architects, not only presented us with a complete set of their valuable and interesting Proceedings, but were good enough to put us upon their books, so that we have since continued regularly to receive the papers they have published. The *Societé Centrale des Architectes* in Paris also send us the papers they from time to time put forth. This beginning of a library was largely added to in the summer of 1872, by means of a fund specially collected for the purpose, so that the books on the shelves now number three hundred and fifty volumes, most of which are excellently suited to the wants of the students and are constantly consulted by them. These books, as well as the photographs, prints and drawings, which also have been largely added to from year to year, are at all times accessible to the students, and are freely used by them. It has not been found that this freedom has been abused to the injury of the collections, and the advantage to the school is so great that it is worth while to run a considerable risk, rather than limit their serviceableness.

Besides the casts, photographs, books and drawings, the most noticeable thing in the collections is the stained glass, a part of which has been purchased, but it is in great part the gift of the makers. It is arranged on four movable screens and comprises work by Messrs. Morris & Co., Lavers, Barraud and Westlake, Heaton, Butler and Bayne, Clayton and Bell, Cottier & Co., J. T. Lyon, and G. E. Cook of London, and Messrs. Cook, and McPherson & Co., of Boston, besides some fragments of mediæval work.

A detailed memorandum of these collections is given in the Appendix.

COURSE OF INSTRUCTION.

The Museum was arranged during the spring and summer of 1868 and the department opened with four pupils, in October of that year. This number has gradually increased until there are now thirty-two students in attendance, ten of whom are regular students in the Institute, pursuing a four years' course of study, and taking architecture in addition to the mathematical and scientific work pursued in other departments of the school. The other twenty-two are special students, pursuing a two years' course which is confined to the strictly professional work. The special students, however, give all their time to their studies, the same as the others; the plan of having students spend part of the day in architects' offices and part at the school was tried for a year or two, but it did not prove satisfactory in any respect, and is now given up.

This professional work consists chiefly in successive exercises in architectural drawing and design, introductory to which are given lectures, with practical exercises, in shades and shadows and in the elements of architecture, beginning with the orders and giving simple rules for laying them out, and going on to doors, windows, staircases, arcades, vaults, domes and roofs. The history of architecture is then taken up, the Greek and Roman history first, which is gone over with every class as soon as they have completed these elementary studies, followed by the history of the Mediæval and of the Modern styles, which for convenience are taken up in alternate years. The more advanced students have lectures once a week on the theory of architecture, and upon the arts specially related to building, such as stained glass, mosaic, color, carving, etc. Once a week throughout the year is a lecture upon specifications and working drawings; carpentry and its related subjects being taken up one year and masonry, etc., the next, so that the whole course occupies two years. This subject is necessarily treated in a somewhat superficial manner, since it is the object of the department to give the instruction that cannot be obtained in

architects' offices, leaving students to learn what can there best be learned during the term of their service as draughtsmen. But the rapid survey these lectures afford is found to be worth the small amount of time it consumes, serving as a sort of review of the subject to those who are already familiar with it, and as a serviceable preparation for office work to others. To both it is useful, as giving a more comprehensive view of the subject than office experience is apt to afford.

Instruction is also given in Perspective, Descriptive Geometry, Stereotomy and Free-hand Drawing. The practice in architectural drawing begins with elementary exercises in india ink, with the pen and with the brush, followed by exercises in the use of india ink and color, beginning with architectural details or fragments on a large scale, and going on to plans, elevations and details, first copied, from books, and, the next year, drawn from actual measurement of buildings in the neighborhood of the school. Drawings have, in this way been made of King's Chapel, the First Church, the Central Church, Emmanuel Church and some others, the spires of Park Street Church, the Old South, Hollis Street Church, and Christ Church in Salem Street, of the principal railway stations in Boston, and of a number of dormer windows and doorways, and details of cast and wrought iron work and of ornamental brick work.

The practice in design begins with simple problems intended as practice in the use of the orders, and goes on gradually to the higher class of monumental work, and to buildings of complicated and difficult plan. Among the subjects of these exercises have been the following: — A Porch to a Private House, a Drive-way, a Campanile, a Peristyle, a Staircase under a vault or dome, the employment of four (or six) columns, a Boat House and Billiard Room, a Pavilion between two Bridges, a Monumental Bridge, the restoration of a Pompeian House, a Lamp Post, a Fountain, a Chimney-Piece, a Vestibule, a Small Museum, a Memorial Library, a Memorial School House, a Railroad Station, an Artist's House, a Monumental Chapel, a Catholic Church, Water Works in a Pub-

lic Park, an Iron Kiosk, a Casino, a Dwelling House, a School of Chemistry, a School of Medicine and a School of Architecture. As the class become more advanced, details upon a larger scale are often required. The time allowed for these problems varies from a couple of days to a couple of months according to the difficulty of the work, the experience of the students, and the number and size of the drawings required. Each class do ten or twelve of these exercises in the course of the year.

The subjects, as will be noticed, are most of them somewhat out of the line of daily experience. More practical problems would require for their solution more practical experience than such classes as these can possibly have had, involving for their solution numerous considerations of detail, which it would not do to slight, but which students in the beginning of their studies are not prepared to entertain. Work of this kind, on the other hand, while it taxes their powers to the utmost, both in the execution of the drawings and in the design, does not demand, for its satisfactory performance, any greater resources either of knowledge or skill, than they have at command. Besides, its remoteness from daily use and observation, not only stimulates the imagination and fancy, but necessitates the study of the books and of the work of the best masters.

The classes are made up, besides the regular students of the Institute, of boys just from school, of mechanics wishing to become draughtsmen in offices, of draughtsmen who have already had office experience and who wish to learn what an office does not give, and of graduates of colleges who desire to enter upon their profession in the most rapid and intelligent way. It is not possible to lay down a strict course of study that shall equally meet all the wants and occupy all the time of persons varying so much in personal training. But the special work of the school is new to all alike and serves equally well for all as their chief interest and object of study. Moreover, the largeness of the company is an advantage, and all would suffer if they were broken up into smaller groups. The work done is equally in-

structive to all, whether the result is more or less excellent in conception or in execution. In point of fact, although at the beginning of the year there is great difference in the work, by the end of the year it is often hard to tell the work of the beginners from that of the more experienced hands. Meanwhile the resources of the establishment are open to all, and as much is done, and as much is learned in volunteer work, especially tracing and sketching, not to speak of reading, as is accomplished under the requirements of the programme. The students learn much more than they are taught, and what they thus teach themselves is not likely to be forgotten.

ARCHITECTURAL PROBLEMS.

December 1.

An Open Porch before a Private House.

The house to which this porch or portico belongs is supposed to be situated in the principal street of a city, the steps of the porch descending to the sidewalk. The upper platform or landing is to be raised nine steps from the sidewalk, the threshold of the front door forming a tenth step. This platform is to be about one hundred square feet in area, more or less. The steps must not be more than six or seven inches high, nor less than twelve inches wide. Balustrades must not be more, nor much less, than three feet in height. The whole is to be constructed of stone, and is to conform in its proportions and its details to the regular rules for the Five Orders. The whole problem is to be regarded as an exercise in the practical application of those rules. If arches are used, they will accordingly be semi-circular.

Required: *A Plan*, showing the platform, steps, sidewalk, and the beginning of the vestibule of the house, the horizontal section being taken at half the height of the columns, and cutting through the front wall of the house and the front doorway.

An Elevation, showing the front of the porch towards the street, and the main doorway at the back of the porch.

A Section, taken through the middle of the porch, and extending to the vestibule.

All these drawings to be made on half an Imperial sheet of Whatman paper, stretched, to a uniform scale of a quarter of an inch to the foot, and finished in pencil, with the shadows cast in India Ink. Color may be added, if desired. The elevation will be set above the plan, on the same

vertical axis, and the section at the side of the elevation. A side elevation may be added, if desired.

This sheet of drawings must be handed in on Monday, December 8.

A Temple Tomb. *December* 3.

It is the custom in some countries to erect over a grave or tomb a small temple or oratory, just large enough to cover it, containing an altar where a single mourner may offer prayers for the dead.

It is required to design such a structure, making it in the form of a small Grecian temple, with two columns, *prostyle*, all the details being Greek rather than Roman in character. The plot of ground is supposed to measure six feet by twelve.

Required : *A Plan, Section, and two Elevations*, on a uniform scale of half an inch to the foot, with details one-eighth full size, all on an Imperial sheet.

A Drive-way. *December* 9.

The object of a Drive-way is almost the same as that of a porch ; it differs only in that it serves as a shelter, not only to pedestrians, but to those who come in carriages. The proposed structure would be part of a rich private house erected on a public square. It must be sufficiently large for a carriage to pass freely under, and at the same time give access to the main hall of the house. The plan must be so arranged that pedestrians need not meet the carriages, in order to avoid accidents. The greatest dimensions of this structure must not exceed 500 square feet. The doorway must be about four steps above the roadway, with proper steps and platforms between.

Required : *A Plan, Section* and *Two Elevations*, on a uniform scale of one-eighth of an inch to the foot, to be drawn in pencil, shaded with India ink, with or without color, the sections to be tinted in carmine, the plan in vermilion, and the whole to be drawn upon a half-sheet of Imperial Whatman, the top of the paper being the narrowest, and to be cut up to a uniform size of 21 inches by 14 inches, with a border within.

The drawings will be handed in on Monday, December 16, at half-past three o'clock in the afternoon. The adjacent parts of the house may be indicated.

A Portico in a Garden. *December* 17.

This little building is supposed to be erected at the extremity of a garden attached to a palace. It is intended for rest and shelter for persons walking in the garden, and also for the reception and protection of a number of

bas-reliefs and statues. It forms the principal object in looking across the garden from the windows of the palace, and should have the architectural character appropriate to its position and uses. It must be of only one story in height, and may be covered either by an inclined roof or by a terrace surrounded by balustrades. There must be in some part walls for the bas-reliefs. But, in general, the structure is not enclosed, and the roof is supported by arcades or colonnades. The width of these openings should not be much less than five nor much more than ten feet. Mansard roofs are not to be used. The greatest linear dimension must not exceed eighty feet. The building must comprise, within or around it, seats for conversation, steps, fountains, vases, &c.

REQUIRED: *A Plan*, on a scale of one-sixteenth of an inch to the foot, showing the arrangement of the garden in the neighborhood of the portico; *A principal Elevation*, and a *Section*, on a scale of one-eighth of an inch to the foot. This difference of scale will be found convenient in practice, as the total dimensions shown on the plan can be laid off on each side of symmetrical axes in elevation.

The whole to be drawn on two-thirds of a sheet of Whatman, the border lines enclosing the sketch being 17 and 19 inches long. To be handed in, drawn in pencil, shaded in pencil or India ink, and tinted, on Wednesday, December 24, at half-past three o'clock. Put your names and the date *on the back of the drawings*, with a minute of the time spent upon them, beginning with this morning's hour.

A PERISTYLE. *December* 29.

We suppose a public building, built on three sides of a hollow square, to be entered by a porch or portico, of six Corinthian columns, surmounted by a pediment and preceded by flights of steps, and situated at the bottom of the court-yard. Elsewhere the court-yard is surrounded by a colonnade, which is interrupted by the portico, and which is of much smaller dimensions. It may be of either order. Arches are not permitted. The hexastyle portico will have columns twenty-five feet high, including base and capital. The size of the others is left to the taste and judgment of the designer.

REQUIRED: *An Elevation* of the portico, showing both orders, on a scale of a quarter of an inch to the foot.

A Side Elevation, showing a section of the colonnade, to the same scale.

A Plan, on a scale of an eighth of an inch to the foot, showing the entrance doorway or doorways and indicating the vestibule within.

These to be drawn on a single sheet of Whatman's Imperial and cut up to a uniform size of 18 inches by 28. To be finished, with the shadows cast in India ink, either in pencil or line, with or without color, on Monday,

January 12, at 3.30 P. M. Put on the back of drawing name, date, and number of hours' work.

A Flower Stand. *January* 2.

This little structure is for the sale of flowers in a public square or park. It must be constructed of iron, open on three sides at least, with projecting roof to give shade. It may be raised on a platform of stone, with balustrades; and is to cover, exclusive of the platform, about one hundred square feet.

Required: *A Plan*, on a scale of a quarter of an inch to a foot; an *Elevation*, double that scale; and details, showing the construction, on a scale of one inch to a foot. All on a single Imperial sheet.

A Grand Staircase. *January* 12.

This staircase is supposed to occupy the central hall or vestibule of some public building, such as a State House, Library, or Museum, in which the principal rooms are in the second story. It must be built of stone or marble. The hall or vestibule is to be covered by a vaulted or domed ceiling, and may be lighted either from above or by windows on one side, where the hall may be supposed to come to an external wall. The form of this hall, as well as that of the vault above and the disposition of the stairway itself, and the means of supporting them, is left to the judgment of each student. The staircase will extend only from the ground floor to the main floor, and the area of the hall will be about 2,000 or 3,000 square feet. The height of stories is not fixed.

Required: I. *A Plan* of the Hall taken at the level of the main story looking down upon the staircase, and showing three doorways, by which access is had to the principal apartments.

II. *Two Sections* taken vertically, at right angles to each other, showing the design of the staircase, of the vaulted or domed roof, and of the hall or vestibule in both stories. All on a uniform scale of $\frac{1}{12}$ in. = 1 ft.

The drawings will be on half sheets of Imperial paper, and will be inked in and colored, with the shadows cast. A brown-paper sketch will be made on Tuesday morning, January 13, and the drawings handed in on Thursday evening, January 22.

A Billiard Room. *February* 4.

This little building is situated on a bank, ten or fifteen feet above a stream navigable for row-boats and wherries, and surrounded elsewhere by gardens, of which it is a principal ornament. It comprises, besides the Billiard Room itself, the following parts: —

1. A Porch, open or enclosed.

2. A semi-circular Veranda, in the Ionic order, without arches.

3. A Belvidere, covering the whole or a part of the building, covered by a roof, but without walls, and communicating with a staircase. This staircase may be either external or internal.

4. A landing for boats, on a level with the water below, with proper steps and balustrades leading up to the garden and Billiard Room.

The Billiard Room itself is to be eighteen feet wide by twenty-four feet long in the clear, exclusive of niches, alcoves, recesses, and seats for spectators of the game. It must be lighted by windows in the side walls, the arrangement and composition of which constitute a chief point in the problem. But light from the roof, over the billiard table, may also be introduced if desired. The table is six feet by twelve.

The walls and cornice of the building are to be of light-colored stone or marble, as also the steps and balustrades. The ceilings may be of wood or plaster, and the roof and eaves of the Belvidere may be of wood.

REQUIRED: *A Plan*, showing the adjacent parts of the garden, steps, landing, &c., on a scale of an eighth of an inch to the foot.

A Principal Elevation, showing the steps down to the landing, on the same scale.

A Section and another Elevation, on a smaller scale.

A Plan of the roofs, looking down.

The whole to be drawn on a single sheet of Whatman's paper, fourteen inches by nineteen inches, finished as a sketch in pencil and color, with the shadows cast in India ink. To be handed in on Monday, February 16, at half-past three o'clock, P. M.

A CAFE. *February* 8.

This building, which is supposed to stand in a park or pleasure garden, must contain: —

1. The café itself, with proper kitchen, serving rooms, supper rooms, and a lodging for the proprietor.

2. A little theatre for singing and dancing, with the stage under cover, but the orchestra and audience out of doors in a garden.

3. Porticos, or covered walks, enclosing this garden,

The greatest dimensions of the plan must not exceed 100 feet.

REQUIRED: *Plan, Section, and Elevation*, finished in color or India ink on a uniform scale of sixteen feet to the inch.

A POMPEIAN HOUSE. *February* 21.

REQUIRED: To take the plan of some house at Pompeii, as given by Mazois, Zahn, Sir William Gell, Falkener, or any other accessible author-

ity, or in the plan of Pompeii, and to draw it out on a convenient scale, say one eighth of an inch to a foot. Also, to make a section on a larger scale, through the different *Cavædia*.

The whole to be finished in color, the ruined parts being restored, the roof added, and the decorations copied or adapted from photographs and prints.

The whole to be finished and handed in on Tuesday, March 10.

THE USE OF FOUR COLUMNS. *March* 5.

A wealthy amateur of the arts is in possession of the shafts of four columns of rich marble, which he wishes to make use of in the erection of a small building or monument. As these columns can serve equally well to form part of a great variety of structures, each student is left free to choose the subject of his composition. It may be a fountain, well, portico, tomb, or any other structure whatever.

These columns are to be taken as twelve feet long, exclusive of base and capital, which are to be supplied. Any substructure or base that the nature of the composition may require may be added.

REQUIRED: *A Plan and Elevation*, both on a scale of one fourth of an inch to the foot, finished in pencil, with the shadows cast, with or without color. To be handed in Tuesday morning, March 10, along with the Pompeian Houses.

A MONUMENTAL BRIDGE. *March* 13.

It is supposed that two neighboring nations, having settled by arbitration a question of boundary, agree to erect over a stream, which forms the frontier determined upon, a bridge, which shall at the same time serve to promote friendly intercourse and to preserve the memory of their compact, as an example to future generations. The stream at the point selected lies a hundred feet below the level of the proposed road, which passing along the slope of the mountain which forms one bank, until it reaches the narrowest part of the ravine, here crosses to the opposite side. The engineers report that good foundation for masonry may be had, if desired, in the bed of the stream. It is necessary to erect at each extremity of the bridge one or two small buildings to serve as custom-houses, with lodgings for the officer in charge, and a guard-room in which to quarter a dozen men on occasion, besides a room for the inspection and weighing of baggage and merchandise. There should also be a small lock-up for the detention of smugglers and other prisoners. Also a gate across the road. From one of these custom-houses to the other the length of the bridge is one hundred feet, and its width, within the parapets, thirty feet, comprising a carriage-way and two narrow foot-ways. In the centre of the bridge, over the middle of the

[illegible] and marking the many beauties [illegible] Temple each in [illegible] of Paris, if such exercises are deemed necessary by the [illegible] composition. The exercises must [illegible] and not less. The custom-houses [illegible] and need not [illegible] built in light and [illegible] and stone in Paris, and are [illegible] to form part of a single architectural composition.

Required: a Plan, Elevation, and Section, showing the [illegible] all on a single Imperial sheet, drawn to a uniform scale of twelve feet to the inch. Sketches to be made by Wednesday, [illegible] and finished drawings to be handed in on Monday, March 26, at half-past three o'clock, P.M.

Sketches to be on the scale of [illegible] inches to the foot, [illegible] give the number of hours' work from this date.

A School of Architecture (No. 1)

We suppose that the vacant lot belonging to the Institute and adjoining the present building has been devoted to our own use, and that the Department is called upon to say what sort of a building is needed for its accommodation. To this end the class will furnish sketches, embracing the following points, with such further suggestions as their observation and experience may supply.

1. An Entrance Hall.
2. Proper staircases.
3. A Public Lecture Room to seat about 200 persons.
4. A Museum of Casts, accessible to the public, and convenient to the lecture room.
5. A Museum of Building Materials and Models.
6. Two small Lecture Rooms for 100 students each, one for history and design, one for construction.
7. One or more rooms for Library and Reading Room.
8. One or more rooms for Architectural Drawing, with accommodations for 100 students.
9. A room for Crayon Drawing, from casts and from the life, and a room for modelling in clay and plaster.
10. A Laboratory for Carpentry, Masonry, Painting, Metal work, etc.
11. A Carpenter's Shop.
12. Four private rooms, two large and two small.
13. Proper provisions for W. C., Wash Rooms, etc.
14. A Lift or Dumb Waiter, and proper Ventilating Shafts.

The building to be built of brick and stone, with two stories each fifteen feet high, and a basement in which may be put some of the rooms. It is desired that the whole building shall cover about 6,000 square feet, and

that it shall not exceed 110 feet in any dimension. The Lecture Rooms should give six or eight square feet to each person, inclusive of aisles and platform. The sketches to be handed in on Tuesday afternoon, April 14, and to comprise two plans and two elevations, in pencil, on a scale of one-sixteenth of an inch to the foot, with the shadows cast in India ink.

A RAILWAY STATION. *April* 4.

A railroad, with double track, is supposed to pass under the main street of a country village. It is proposed to cross it by an arched bridge of a single span, and to build the station upon this bridge. It is to be of wood, stone, or brick, and iron, and to comprise, besides the ordinary waiting-rooms, baggage-rooms, and offices, convenient verandahs, and covered stairways leading down to the platforms, on a level with the tracks.

REQUIRED: *A Plan, Section, and two Elevations*, on a scale of eight feet to an inch, and a third elevation and a plan of the roofs on a smaller scale, all on one sheet of Imperial.

ALSO: A portion of the building drawn out on a scale of half an inch to the foot, with details on a scale of one inch to the foot.

STUDENTS WHO ARE CANDIDATES FOR A DEGREE will present these drawings as part of their Graduating Thesis, and will submit along with them calculations of the strength and stability of the principal parts of the structure.

The work must be done by the 15th of May.

APPENDIX.

CORPORATION FOR 1875–76.

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Secretary,	**Treasurer,**
SAMUEL KNEELAND.	JOHN CUMMINGS.

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THOMAS T. BOUVÉ,	WILLIAM B. ROGERS,
J. ELIOT CABOT,	J. BAXTER UPHAM,
GEORGE B. EMERSON,	

Treasurer, *ex-officio.*

Committee on Finance,

HENRY P. KIDDER, *Chairman,*	JOHN M. FORBES,
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WILLIAM ENDICOTT, JR.,	SAMUEL D. WARREN,

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Committee on the Museum,

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JOSEPH S. FAY,	STEPHEN P. RUGGLES,
AUGUSTUS LOWELL,	NATHANIEL THAYER.
HORACE McMURTRIE,	

Committee on the Society of Arts,

MARSHALL P. WILDER, *Chairman,*	J. C. HOADLEY,
PHILLIPS BROOKS,	FRED. W. LINCOLN,
J. WILEY EDMANDS,	SAMUEL K. LOTHROP,
CHARLES L. FLINT,	ALEXANDER H. RICE,
JAMES B. FRANCIS,	HENRY B. ROGERS.

On the Part of the Commonwealth,

HIS EXCELLENCY, GOVERNOR ALEXANDER H. RICE.

HON. HORACE GRAY, *Chief Justice of the Supreme Court.*

HON. JOSEPH WHITE, *Secretary of the Board of Education.*

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C. L. FLINT.
J. B. FRANCIS.
JOHN D. RUNKLE.

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W. B. ROGERS.
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F. W. LINCOLN.

Mining Engineering.

T. T. BOUVÉ.
JOS. S. FAY.
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W. B. ROGERS.

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J. ELIOT CABOT.
C. L. FLINT.
J. D. PHILBRICK.

Mechanics.

J. D. RUNKLE.
J. INGERSOLL BOWDITCH.
J. C. HOADLEY.
E. S. PHILBRICK.
STEPHEN P. RUGGLES.

Free Hand and Mech. Drawing.

J. D. PHILBRICK.
PHILLIPS BROOKS.
C. H. DALTON.
H. P. KIDDER.
J. B. UPHAM.

Military Science and Tactics.

J. B. UPHAM.
C. H. DALTON.
E. R. MUDGE.
H. McMURTRIE.
A. H. RICE.

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J. D. RUNKLE.
J. B. FRANCIS.
J. A. LOWELL.
H. McMURTRIE.
A. H. RICE.

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J. A. LOWELL.
EDWARD ATKINSON.
J. L. LITTLE.
E. R. MUDGE.
A. H. RICE.

Descrip. Geometry and Stereotomy.

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J. C. HOADLEY.
H. McMURTRIE.
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Professor of Mathematics.

EDWARD C. PICKERING, S.B.,
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Professor of General Chemistry.

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Professor of Modern Languages.

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Professor of Topography.

HENRY MITCHELL, A.M., U. S. Coast Survey,
Professor of Physical Hydrography.

ALPHEUS HYATT, S.B., Custodian of the Boston Society of Natural History,
Professor of Paleontology.

* The instruction in Botany is at present given by Prof. Ordway.

[illegible], A.B.,
Instructor in [illegible]

[illegible], S.B.,
Instructor in [illegible]

[illegible], S.B.,
Instructor in [illegible]

[illegible], S.B.,
Instructor in [illegible]

[illegible], S.B., C.E.,
Instructor in [illegible]

[illegible],
Assistant in Architecture

[illegible], S.B.,
Instructor in [illegible]

JULES LUQUENS, Ph.D.,
Instructor in Modern Languages

CHARLES KASTNER,
Lateral Instructor in French Design

WEBSTER WELLS, S.B.,
Instructor in Mathematics and Descriptive Geometry

THOMAS E. POPE, A.M.,
Instructor in Quantitative Analysis

FRANK B. [illegible], S.B.,
Instructor in Freehand Drawing

HENRY K. MUTCH,
Instructor in Mechanical and Freehand Drawing

WILLIAM FOSTER,
Assistant in the Mining and Metallurgical Laboratories

FRANCIS T. SARGENT, S.B.,
Assistant in Mechanical Engineering

J. AUSTIN KNAPP, S.B.,
Assistant in Mechanical Engineering

LEWIS M. NORTON,
Assistant in Quantitative Analysis

CHARLES C. R. FISH,
Assistant in General Chemistry and Qualitative Analysis

WILLIAM E. NICKERSON,
Assistant in General Chemistry and Qualitative Analysis

WILLIAM O. CROSBY,
Assistant in Paleontology

CONDITIONS OF ADMISSION.

To be admitted as a regular student of the first year's class, applicants must have attained the age of sixteen years, and must pass a satisfactory examination in arithmetic (including the metric system of weights and measures), algebra through equations of the second degree, plane and solid geometry, including spherical geometry, French grammar through regular and irregular verbs, and the first two books of Voltaire's "Charles XII" (*i.e.*, about sixty pages) or the equivalent of the same, English grammar, including, especially, the ability to detect the parts of speech, to use correctly the conjugation of verbs regular and irregular, to classify terms as Singular, General, and Universal, and to analyze phrases and sentences, English composition, rhetoric (so much as is included in the first part of Bain's Rhetoric, or its equivalent), history of the United States, and geography. In general, the training given at the best High Schools, Academies, and Classical Schools, will be a suitable preparation for this School.

Graduates of Colleges will, in general, be presumed to have the requisite attainments for entering the third year as regular students, and may do so on satisfying the department which they purpose to enter that they are prepared to pursue their studies to advantage. Such students, if deficient in any of the scientific studies of the first two years, will have opportunities for making them up without extra charge, and will be required to pass an examination in them before entering upon the studies of the fourth year. Should they be already proficient in any of the general studies of the third and fourth years, they will be excused, if they wish, from attendance on the exercises in these subjects.

REGULAR COURSES.

ALL COURSES. — FIRST YEAR.

			No. of Exercises	Hrs. per week
1	Algebra finished	1st half	45	3
	Plane and Solid Geometry reviewed . .	2d half	15	3
	Plane and Spherical Trigonometry . .	2d half	30	3
2	General Chemistry	1st half	60	6
	General Chemistry	2d half	30	2
	Qualitative Analysis	2d half	30	4
3	Structure of the Sentence.	1st half	30	2
	Rudiments of Logic	2d half	30	2
4	French		90	3
5	Mechanical Drawing and Elements of Descriptive Geometry and Perspective .		90	6
6	Free Hand Drawing		90	3
7	Physiology and Hygiene	2d half	30	2
8	Military Tactics		90	3

I. CIVIL ENGINEERING.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Analytic Geometry	1st half	45	3
	Calculus	2d half	45	3
2	Descriptive Geometry	1st half	30	2
	Mechanical Drawing	1st half	30	4
	Surveying		60	2
	Topographical and Plan Drawing	2d half	30	4
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

1	Survey and Location of Roads	1st half	45	6
	Construction of Roads	2d half	20	6
	Water supply, Drainage, etc.	2d half	25	6
	Field Practice		30	3
	Stereotomy	1st half	30	4
	Bridge and Roof Construction	2d half	30	4
2	Calculus	$\frac{1}{4}$ year	25	3
	Applied Mechanics	$\frac{3}{4}$ year	65	3
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Stability of Structures	1st half	20	6
	Strength of Materials	1st half	25	6
	Structures of Stone	2d half	15	6
	Structures of Wood	2d half	10	6
	Structures of Metal	2d half	20	6
	Topography (Field Practice)	2d half	10	
	Physical Hydrography	2d half	10	
	Structure Drawing	2d half	45	6
	Building Materials	2d half	10	3
2	Water power and Water wheels	2d half	25	4
3	Metallurgy of Iron	1st half	30	2
4	Applied Physics	1st half	30	2
5	German	1st half	45	3
6	Philosophy of Science	1st half	45	3

In addition to the prescribed studies, optional studies, selected from other courses, may be taken.

II. MECHANICAL ENGINEERING.

SECOND YEAR.

			No. of Exercises	Hrs. per week.
1	Analytic Geometry	1st half	45	3
	Calculus	2d half	45	3
2	Descriptive Geometry	1st half	30	2
	Mechanical Drawing	1st half	30	4
	Principles of Mechanism	1st half	30	2
	Principles of Mechanism	2d half	60	4
	Machine Drawing	2d half	30	4
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

1	Machinery and Millwork	$\frac{3}{4}$ year	80	6
	Strength of Materials	$\frac{1}{4}$ year	40	6
	Mechanical Laboratory		30	2
	Machine Drawing		60	4
2	Calculus	$\frac{1}{4}$ year	25	3
	Applied Mechanics	$\frac{3}{4}$ year	65	3
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Principles of Thermodynamics	1st half	90	6
	Mechanism of the Steam Engine	2d half	50	3
	Water power and Water wheels	2d half	70	3
	Machine Drawing		90	6
	Mechanical Laboratory		105	7
	Building Materials	2d half	10	3
2	Metallurgy of Iron	1st half	30	3
3	German	1st half	45	3
4	Philosophy of Science	1st half	45	3

In addition to the prescribed studies, optional studies, selected from other courses, may be taken.

III. MINING ENGINEERING.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Analytic Geometry	1st half	45	3
	Calculus	2d half	45	3
2	Qualitative Analysis	1st half	45	6
	Drawing	1st half	30	2
	Mineralogy	2d half	45	6
	Botany	2d half	30	2
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

1	Chemical Laboratory		150	10
	General Quantitative Analysis (Lectures)	1st half	30	2
	Mining Engineering		90	3
	Assaying	2d half	15	3
	Structural Palæontology	2d half	15	2
2	Calculus	$\frac{1}{2}$ year	25	3
	Applied Mechanics	$\frac{3}{4}$ year	65	3
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Ore dressing	$\frac{1}{2}$ year	15	3
	Metallurgy	$\frac{1}{2}$ year	45	3
	Drawing	1st half	30	2
	Mining and Metallurgical Laboratory	2d half	75	10
	Chemical Laboratory		150	10
2	American Geology	1st half	40	3
	Coal and Ore Deposits	2d half	15	3
	Building Materials	2d half	10	3
	Chemical Geology	2d half	15	3
3	German	1st half	45	3
4	Philosophy of Science	1st half	45	3

In addition to the prescribed studies, optional studies, selected from other courses, may be taken.

IV. ARCHITECTURE.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Analytic Geometry	1st half	45	3
	Calculus	2d half	45	3
2	Descriptive Geometry	1st half	30	2
	Mechanical Drawing	1st half	30	4
	Shades, and Shadows	2d half	30	2
	The Orders	1st quar.	16	2
	Greek and Roman Arch. History	2d quar.	14	2
	Architectural History and Design	2d half	30	2
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

1	Theory of Architecture	1st half	15	1
	Architectural History and Design	2d half	30	2
	Stereotomy	1st half	30	4
	Mechanical Drawing	1st half	30	4
	Architectural Drawing		150	10
	Specifications and Working Drawings		30	1
2	Calculus	½ year	25	3
	Applied Mechanics	½ year	65	3
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Architectural History and Design		30	1
	Architectural Ornament and Detail		30	1
	Specifications and Working Drawings		30	1
	Architectural Drawing		150	10
2	Stability of Structures	1st half	20	6
	Strength of Materials	1st half	25	6
	Structures of Stone	2d half	15	6
	Structures of Wood	2d half	10	6
	Structures of Metal	2d half	20	6
	Building Materials	2d half	10	3
3	Applied Physics	1st half	30	2
4	German	1st half	45	3
5	Philosophy of Science	1st half	45	3

In addition to the prescribed studies, optional studies, selected from other courses, may be taken.

V. CHEMISTRY.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Qualitative Analysis	1st half	45	6
	Mineralogy	2d half	45	6
2	Chemical Philosophy	1st half	45	3
	Botany	2d half	30	2
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science and Tactics		24	1

THIRD YEAR.

	Chemical Laboratory		150	12
	General Quantitative Analysis (Lectures)	1st half	30	2
	Quant. Anal., Special Methods (Lectures)	2d half	30	2
	Industrial Chemistry	2d half	45	3
2	Chemical Physiology	1st half	30	2
	Structural Palæontology	2d half	15	2
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Chemical Laboratory		150	15
	Organic Chemistry (Lectures)		60	2
	Metallurgy	½ year	45	3
	Drawing	1st half	30	2
2	American Geology	1st half	40	3
	Chemical Geology	2d half	15	3
	Coal and Ore Deposits	2d half	15	3
	Building Materials	2d half	10	3
	Assaying	2d half	10	
3	Applied Physics	1st half	30	2
4	German	1st half	45	3
5	Philosophy of Science	1st half	45	3

In addition to the prescribed studies, optional studies, selected from other courses, may be taken.

VI. METALLURGY.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Qualitative Analysis	1st half	45	6
	Mineralogy	2d half	45	6
2	Chemical Philosophy	1st half	45	3
	Botany	2d half	30	2
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

	Chemical Laboratory		150	12
	General Quantitative Analysis (Lectures)	1st half	30	2
	Quant. Anal., Special Methods (Lectures)	2d half	30	2
1	Industrial Chemistry	2d half	45	3
2	Chemical Physiology	1st half	30	2
	Structural Palæontology	2d half	15	2
	Assaying	2d half	15	3
3	German		90	3
4	Physical Laboratory		60	2
1	Outlines of Zoology, or History	1st half	30	2
5	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

6	Ore-dressing	1 year	15	3
	Metallurgy	1 year	45	3
	Drawing	1st half	30	2
	Mining and Metallurgical Laboratory	2d half	15	11
	Chemical Laboratory		120	21
2	American Geology	1st half	45	3
	Coal and Ore Deposits	2d half	15	3
	Building Materials	2d half	15	3
	Chemical Geology	2d half	15	3
5	German	1st half	45	3
4	Philosophy of Science	1st half	45	3

In addition to the prescribed studies, optional studies, selected from other courses, may be taken.

VIII. PHYSICS.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Analytic Geometry	1st half	45	3
	Calculus	2d half	45	3
2	Qualitative Analysis	1st half	45	6
	Quantitative Analysis	2d half	45	6
	Chemical Philosophy	1st half	45	3
	Botany	2d half	30	2
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

1	Physical Laboratory		120	4
	Physics (additional Lectures)		60	2
2	Calculus	½ year	25	3
	Applied Mechanics	½ year	65	3
	Strength of Materials	2d half	30	4
3	General Quantitative Analysis (Lectures)	1st half	30	2
	Chemical Physiology	1st half	30	2
	Chemical Laboratory	1st half	45	6
4	German		90	3
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Physical Research		150	10
	Advanced Physics		30	2
	Photography	1st half	15	4
	Lantern Projections	1st half	15	4
2	Chemical Laboratory	2d half	75	10
3	Practical Astronomy	1st half	30	3
	Mechanical Engineering	1st half	15	3
4	Principles of Thermodynamics	1st half	60	4
5	American Geology	1st half	40	3
	Chemical Geology	2d half	15	3
	Coal and Ore Deposits	2d half	15	3
	Building Materials	2d half	10	3
6	German		90	3
7	Philosophy of Science	1st half	45	3
	Political and Industrial Geography	2d half	30	

In addition to the prescribed studies, optional studies selected from other courses, may be taken.

VII. NATURAL HISTORY.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Chemical Philosophy	1st half	45	3
	Botany	2d half	30	2
2	Qualitative Analysis	1st half	45	6
	Mineralogy	2d half	45	6
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

1	General Quantitative Analysis (Lectures)	1st half	30	2
	Comparative Zoology	2d half	45	3
	Chemical Laboratory		150	10
2	Chemical Physiology	1st half	30	2
	Structural Palæontology	2d half	15	2
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Special Zoology, Special Geology, Special Botany, or Special Stratigraphical Palæontology	Laboratory	180	12
2	American Geology	1st half	40	3
	Coal and Ore Deposits	2d half	15	3
	Building Materials	2d half	10	3
	Chemical Geology	2d half	15	3
3	Applied Physics	1st half	30	2
4	German		90	3
5	Philosophy of Science	1st half	45	3
	Political and Industrial Geography	2d half	30	2

In addition to the prescribed studies, optional studies, elected from other courses, may be taken.

IX. SCIENCE AND LITERATURE.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Rhetoric and English Literature . . .		90	3
	Elements of Philosophy	2d half	45	3
2	Chemical Philosophy	1st half	45	3
	Botany	2d half	30	2
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Descriptive Astronomy	1st half	30	2
	Physical Geography	2d half	30	2
6	Military Science		24	1

THIRD YEAR.

1	History		90	3
2	Advanced French		90	3
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology	1st half	30	2
	General Geology	2d half	30	2
6	History of Commerce and Industry . .	1st half	30	2
	Political Economy	2d half	30	2

FOURTH YEAR.

1	Earlier English Literature	1st half	45	3
	Science of Language	2d half	45	3
2	Business Law	1st half	30	2
	Political and Industrial Geography . .	2d half	30	2
3	American Geology	1st half	40	3
	Chemical Geology	2d half	15	3
	Coal and Ore Deposits	2d half	15	3
	Building Materials	2d half	10	3
4	German		90	3
5	Constitutional History		60	2
6	Philosophy of Science	1st half	45	3
	Applied Physics	1st half	30	2

In addition to the prescribed studies, optional studies selected from other courses, may be taken.

X. PHILOSOPHY.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Applied Logic	1st half	45	3
	Elements of Philosophy, viz.,	2d half	45	3
	(a) Its Definition and General Problems (5 lectures)			
	(b) The Solutions proposed by the several Schools (10 lectures).			
	(c) Résumé of Terminology (5 lectures)			
	(d) Outlines of Psychology (25 lectures)			
2	French finished, German begun		90	3
3	Analytic Geometry	1st half	45	3
	Calculus	2d half	45	3
4	Physics (Lectures)		90	3
5	Chemical Philosophy	1st half	45	3
6	English Literature	2d half	45	3
7	Military Science		24	1

THIRD YEAR.

1	Philosophy: Critical History of Modern Systems		150	5
	(a) Descartes, Spinoza, Locke. (1st half, 75 lectures.)			
	(b) Leibnitz, Berkeley, Hume. (2d half, 60 lectures.)			
	(c) Reid, the Transition to Kant. (2d half. 15 lectures.)			
2	Advanced French		90	3
3	German		90	3
4	History	1st half	30	2
	Political Economy	2d half	30	2
5	Physical Laboratory	1st half	30	2
	General Geology	2d half	30	2

FOURTH YEAR.

1	Philosophy: Critical History of Modern Systems		150	5
	(a) Kant and Fichte. (1st half. 75 lectures.)			
	(b) Schelling and Hegel. (2d half. 75 lectures.)			
2	Philosophy of Science, viz.,	1st half	45	3
	(a) Theory of Induction—its precise nature as a Mental Process, its Conditions of Application, and its Five Auxiliary Methods (20 lectures).			
	(b) Classification of the Natural Sciences, with discussion of their Logical Connexion, and of the Logical System of each (10 lectures).			
	(c) Same treatment of the Mathematical Sciences (5 lectures)			
	(d) Logical Theory of the Calculus (10 lectures)			
	Science of Language	2d half	45	3
3	German		90	3
4	Earlier English Literature	1st half	45	3

In addition to the prescribed studies, optional studies selected from other courses, may be taken.

ARCHITECTURAL DEPARTMENT.—BOOKS.

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A.	1.	Barbazat's Iron-work. 4to. 1867.
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	5.	Domestic Economy (Heating and Cooking). C. Sylvester. 4to. 1819.
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	9.	Downing's Landscape Gardening. 1841.
	10.	Béton Coignet. L. F. Beckwith. 8vo. 1868.
	11.	Carpenter's Ancient Carpentry. 1736.
	12.	Haupt on Bridge Construction. 1868.
B.	1, 6.	Fergusson's Handbook. 2 Vols. 3 copies. 1855.
	7, 10.	" History. 3 Vols. 1868.
C.	1–3.	Stuart's Dictionary of Architecture. 3 Vols.
	4.	Rickman's Gothic Architecture. 1862.
	5, 6.	Parker's Glossary. 2 Vols. 1841.
D.	1–6.	Murray's English Cathedrals. 6 Vols.
E.	1–5.	Gwilt's Encyclopedia of Architecture.
	6–7.	Billington's Architectural Director. 2 Vols. 1848.
	8.	Chambers's Civil Architecture. 4to.
F.	1.	Grüner's Fresco Decoration in Italy. Text.
	2, 3.	Proceedings of the American Institute of Architects. 2 Vols. 18 –1875.
	4.	Archæological Proceedings. Winchester. 1865.
	5.	Essex Archæological Society. 1848.
	6–20.	Papers of Architectural Institute of Scotland. 1850–1858.
G.	1.	Architectural Drawing Book. R. S. Burn. 1857.
	2.	Architectural Design. R. S. Burn. 1853.
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		6. Mechanics. Tomlinson.
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	5.	Perspective Linéaire. Thibault.
	6.	Traité d'Architecture. Simonin and Thierry.
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	5.	Cottages for the Laborer. Wood. 1792.
	6.	Grüner's Terra Cotta Work in Italy. 1867.
	7–11.	Architectural Association Sketch Book. London, 1868–1873.
AL.	1.	Ungewitter. Zeigel-und-Stein arbeiten.
	2.	" Gothischen Mödeln.
	3.	" Mittelaltlicher ornamentik.
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B.		St. Mark's. 22.
C.		Churches. 44.
D.		Miscellaneous. 36.
E.		Ducal Palace. 32.
F.	Florence. 53.	
G.	Genoa, Milan. 30.	
H.	Pisa, Parma. 21.	
I.	Padua, Vicenza, Piacenza. 18.	
J.	Orvieto, Bologna, Pistoja, Siena, Perugia. 19.	
K.	Verona. 15.	
L.	Lucca, Ancona, etc. 20.	
M.	Miscellaneous Europe. 30.	
N.	Naples, Pæstum. 24.	
O.	Frescoes and Mosaics. 57.	
P.	Pompeii. 45.	
Q.	Busts, Armor, Vases, Bas Reliefs. 43.	
R.	Ravenna. 40.	
S.	Statues. 52.	
T.	The Old Masters. 56.	
U.	Raphael and Michael Angelo. 54.	
V.	Normandy. 29.	

Portfolio.

W. French Chateaux. Oxford. 24, 26.
X. Rome. 45.
Y. Rome. 50.
Z. Rome. 48.
AA. England. York, Durham. 36.
BB. Salisbury, Bristol, Chichester, 33.
CC. Norwich, Lincoln, Ely. 31.
DD. Winchester, Romsey, Arundel, Parish Churches. 45.
EE. Scotland. Edinburgh. 53.
FF. Glasgow, etc. 33.
GG. Drawings of Modern Buildings. 21.
HH. Modern Buildings. 20.
II. England. Drawings of Modern Buildings. 30.
JJ. Modern Buildings. 36.
KK. America. Drawings of Modern Buildings. 47.
LL. Modern Buildings. 32.
MM. Buildings in Boston. 25.
NN. Miscellaneous Architectural Ornament. 42.
OO. Spain. 75.
PP. New Law Courts, Drawings. 61.
QQ. Melrose Abbey. 40.
RR. English Drawings. 25.
SS. Scenery. 15.
TT. Decoration, Glass, etc. 32.
UU. Italy. (Large.) 43.
VV. Paris. 51.
WW. France. 53.
XX. Louvre and Tuileries. 60.
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AC. Pompeii, etc. 45.
AD. Rome, etc. 48.
AE. Roman Empire. 51.
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AG. Renaissance. 30.
AH. Ecole des Beaux-Arts. 25.
AI. Institute of Technology. 23.

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America.	73.	America.	7.
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MMMM. " " American. 83.

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2. Corinthian Capital from Temple of Castor and Pollux, with Base and Architrave. One-hlaf full size.
3. Doric Entablature of Temple of Hercules, with Capital and Base; one-quarter full size.
4. Doorway of the same, one-tenth full size.
5. Frontispiece. Various Fragments, one-quarter full size.
6. The Doric Order of the Temple of Marcellus. Copy of the original of Mr. André.

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A Monastery. Mr. Felix Escalier.

7. Ground Plan.
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21. Elevation.

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22. Plans.
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24. Section.

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26. Elevation.
27. Section.

A Small Museum. Mr. Létang.

28. Plan, with grounds.
29. Elevation.
30. Section.

An Hotel-de-Ville. Mr. Létang.

31. Two Plans and Sections.
32. Elevation.

A Palais d'Industrie. Mr. Létang.

33. Plan.
34. Section.
35. Elevation.

A Mairie. Mr. Létang.

36. Plan.
37. Section.
38. Elevation.

An Archiepiscopal Palace. Mr. Forget.

39. Plan.
40. Elevation.

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41. Plans.
42. Elevation.
43. Section.

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44. Section.

A Pulpit and Canopy. Mr. Forget.

45. Elevation. (Sketch in India Ink.)

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47. Detail of the Order.
48. Frontispiece. Perspective View.

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49. Plan and Section.
50. Elevation.
51. Frontispiece. Detail of the Order.

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52. Plan and Section.
53. Elevation.
54. Frontispiece. Detail of the Order.

The Same. Mr. E. Calinaud.

55. Elevation.

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56. Plan and Elevations.
57. Woodwork.
58. Ironwork.
59. Stonework.

A Church. Construction Générale. Mr. Victor Hoyot.

60. Plan and Elevations.
61. Details on larger Scale.
62. Woodwork.
63. Stonework.
64. Ironwork.

A Salle de Pas Perdus. Construction en Fer. Mr. Létang.

65. Plan and Elevation.
66. Section and Details.
67. Details.

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Six Competition Drawings for a Church at Lille. Mr. Calinaud.

68. Plan.
69. Front Elevation.
70. Side Elevation.
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75. Interior of a Modern English Church.
76. Design for a Lighthouse. Mr. Rozier and Mr. Létang.
77. Design for an Observatory. Mr. Létang.

LARGE PRINTS.

1. Fac Simile of Perspective View of a Greek Temple. Mr. Viollet-le-Duc.
2. Fac Simile of Perspective of the Baths of Caracalla. Mr. Viollet-le-Duc.
3. Fac Simile of Original Drawing of Front of Cologne Cathedral. One-half size.
4. Fac Simile of Original Drawing of Front of St. Stephen' at Vienna.
5. Bird's Eye View of Paris, in 1845.

DEPARTMENT OF ARCHITECTURE. CASTS.

GREEN ROOM (LIBRARY).

1. Roman decorated moulding. Pantheon.
2. " " "
3. " " " "Jupiter Tonans."
4. " " "
5. Fragment of Colossal Pilaster, from the Villa Medicis.
6. Leaf from the same.
7. Roman Acanthus. Vatican.
8. Another. Rome.
9. Another.
10. Greek Bas Relief. Fragment of Vase.
11. Another.
12. Portion of Greek Scroll. Athens.
13. Roman Acanthus.
14. " Cymatium, decorated.
15. French " " Paris.
16. Acanthus, from Nature.
17. Gothic Capital from Notre Dame.
18. Another.
19. Roman Rosette. Paris.
20. " " Rome.
21. Hand.
22. Fist.
23. Three colossal Ears.
24. Eagle's Head. Rome.
25. Eye, and part of Nose.
26. Another.
27. Female hand.
28. Foot.

29. Ram's head from Candelabra, Vatican.
30. Another. Modern.
31. Bunch of Grapes.
32–40. Casts of Fruit.
41–44. Casts of Fruit and Leaves.
45, 46. Casts of Leaves and Flowers.
47. Lion's Leg.
48. The same, beneath the Skin.
49. Roman Egg and Dart Moulding. Temple of Jupiter Tonans.
50. Greek Egg and Dart Moulding.
51–55. Five Greek Anthemions, from Funeral Monuments.
56–61. Six " " from Terra Cotta Cornices.
62–64. Three Pilaster Capitals. Roman.

RED ROOM.

Casts from Angel Choir, Lincoln Cathedral; round the top of the Room.

65. Angel with Scroll.
66. Virgin and Child. Angel bearing Censer.
67. Christ showing his Wounds. Angel bearing a Soul in a Napkin.
68. Angel with Censer.
69. Angel with Lute.
70. Angel with Scroll and Palm-branch.
71. Angel with Lute. (Duplicate of 59.)
72. Angel with Falcon.
73. Angel bearing a Soul in a Napkin.
74. Angel crowned, with Harp. (? King David.)
75. Angel with closed Book.
76. Angel with open Book.
77. Angel with Viol and Bow.
78. Angel with Scroll.
79. Portion of Arch. Moulding below Spandrels, with Woman's Head as Corbel.
80. The same, with Head of a Lady.
81. " with Head of a Man.
82–103. Twenty-two similar Heads of Priests, Women, Negroes, Men, and Fools.
104–107. Four Carved Bosses.
108–113. Six Square Pieces of Foliage.

South side of Room. Gothic Sculpture and Carvings.

114. Group. King and Queen. Lincoln.
115. " Doctors Disputing. "
116. " Lady and Courtier, with Lap Dogs. Lincoln.

117–121. Five Grotesque Heads. French.
122. Carved Head in Stone. Modern.
123. " Wood. "
124. Small Head and Moulding. Southwell.
125. Corbel, with Mask and Foliage, from Palace of Louis IX.
126. Colossal Head of the Virgin, from Central Doorway, Rheims Cathedral.
127, 128. Angels with Musical Instruments. Notre Dame, Paris.
129, 130. Angels with Candle-sticks. St. Denis.
131. "*Vierge à la Coquille*," from Choir of Notre Dame, outside.
132. Colossal Head of the Prophet Ezekiel, Rheims Cathedral.
133. Corbel with Mask and Foliage, from Palace of Louis IX.
134, 135. Gargoyles, from Notre Dame.
136. Statuette. Nanthilde, St. Denis.
137–139. Three Misereres. Rouen.
140. Corbel with Angels singing.
141. Statuette. St. John.
142. Head. Godfrey de Bouillon.
143. Angel from Arch of Doorway, Notre Dame.
144. Censer. Notre Dame.
145. Triptych.
146. Censer. Chartres.
147–150. Four Monks, from Tombs of Dukes of Burgundy, Dijon.
151. Sitting Monk. Amiens.
152. Moulding with Lily.
153. Ivy.
154. Foliage.
155. Grotesques and Foliage. Flamboyant.
156. Foliage. Flamboyant.
157, 158. Weeping Monks. "*Pleureurs de Bourges*," from the Monument of Jean, Duc de Berri.
159–164. Six Casts from Ivory Carvings.
165–169. Five Panels from North Doorway of Rouen Cathedral.
170–172. Three Sculptured Crosses. Chartres.
173, 174. Two Sculptured Corbels.
175. Hands holding Book. Chartres.
176. Another.
177, 178. Sculptured Embroidery. Chartres.
179–187. Nine Heads from Choir Screen. Chartres.
188, 189. Foliage from Southwell Minster.
190. Mistletoe, Lizard and Snake. French.
191. Boy Climbing. French.

192, 193. Two Spandrels, with Foliage. Southwell Minster.
194, 195. Two Spandrels, with Figures.
196. Panel from Tomb of St. Firmin. Amiens.
197. Imp, from wall at side of the Choir. Lincoln.
198–207. Ten Angels, in panels, with Musical Instruments.
208. Three panels, with similar angel.
209. Figure from Niche. Man and Dog.
210. Figure from Niche.
211–217. Seven Bosses from Cloisters of Lincoln Cathedral. (The originals in Wood.)
218. Panel with Quatre-foils.
219. Spandrel with Foliage.
220. Spandrel with Half-figure.
221. Spandrel with Bat, from Choir and Screen. Notre Dame.
222. Spandrel with Grape-vine. Notre Dame.

West side of Room.

223–224. Byzantine Capitals from Bonn.
225. Byzantine Scroll. Man and Animals. Bonn.
226. " Men Fighting. "
227. Byzantine Panel.
228. Another.
229, 230. Two Capitals from Aix-la-Chapelle.
231. Large Capital from Moissac.
232. Small Byzantine Capital.
233. Large Byzantine Arch Moulding. Germany.
234–235. Two small Byzantine Capitals.
236–237. Two Fragments of Byzantine Columns.

238. Pilaster with Scroll. Chartres.
239, 240. Two Crockets from Notre Dame.
241. Crocket.
242, 243. Two Poppy Heads.
244, 245. Two small Corbels. Notre Dame.
246. Panel. Fleur-de-lys. Notre Dame.
247. Gothic Leaf.
248. Leaf.
249–266. Eighteen Fragments of French Gothic Foliage.
267–280. Fourteen Small Gothic Capitals. French.
281–284. Four Small Spandrels, Carved. French.

[illegible]

[illegible]

[illegible]

352–357. Six Pieces of Foliage.
358. Fragment of Corbel.
359–366. Eight Capitals from Chapter House. Southwell.
367–374. Eight Clustered Capitals. Southwell (?)
375. Misereres. The Resurrection, with Mary Magdalen and the Gardener.
376. The Good Samaritan.
377. King's Head, with Tudor Flowers on the Crown and Collar of Fleur-de-lys.
378. King on Throne, between two Griffins.
379. The Ascension.
380. The same, with Angels swinging Censers.
381. Duplicate of 375.
382, 383. Knight and Four Dragons. (Duplicates.)
384, 385. Samson and the Lion. (Duplicates.)
386, 387. Elephant and Castle. (Duplicates.)
388. Duplicate of 379.
389. Finial from the Cantilupe Chantry, Lincoln.
390, 391. Two Decorated Niches, with Figures. Southwell.

East side of Room. Greek and Roman Sculpture.

392. Mask of Venus of Arles.
393. Mask of Jupiter.
394. Mask of Caracalla.
395. Venus of Milo (reduction).
396. Minerva. (From Bronze.)
397. Victory. (From Bronze.)
398. Euterpe (reduction). Louvre.
399. Head. Bacchante.
400. Head. Neapolitan Psyche.
401. Head of "*Joueuse d'osselets.*"
402. Head of Somnus. (From Bronze.) London.
403. Head of Indian Bacchus (reduction).
404. Faun of the Capitol (reduction).
405. Germanicus (reduction). Louvre.
406. Silenus and Bacchus (reduction). Louvre.
407. Faun Piping (reduction). Vatican. Janus Head.
408. Head of Jupiter Trophonius. (From Bronze.)
409. The "*Joueuse d'osselets*" (reduction).
410. Fates from Parthenon (reduction), restored.
411. Muse (reduction).
412. Apollo Musagetes (reduction).

413. Muse (reduction).
414. Plato. (Terra Cotta, Bronzed.)
415. Caracalla. " "
416. Socrates. (Terra Cotta, Bronzed.)

14 Casts from small Antique Bronzes.

417. Dancing Girl.
418. Etruscan Figure.
419. Jester.
420. Cæsar.
421. Jupiter.
422. Antinous.
423. Boxer.
424. Flute-player.
425. Antinous.
426. Meleager.
427. Theseus.
428. Ball-player.
429. Gladiator.
430. Hercules.
431. Two Masks.
432. Horse's Head from Parthenon.
433. Eagle, from the Vatican.

GRAY ROOM.

South side of Room.

434. Bas Relief. Griffin. Vatican.
435. Honey-suckle Ornament from Pompeii.
436. Scroll.
437. Patera. Temple of Jupiter Tonans.
438, 439. Two small Rosettes.
440. Base Moulding. From Pedestal of Trajan's Column.
441. Chain Ornament.
442. Foliage.
443–450. Eight Rosettes from Tomb of the Scipios.
451. Acanthus Foliage.
452. Greek Moulding.
453. Moulding and Lion's Head. Metapontus.
454–473. Twenty Slabs from the Frieze of the Parthenon. (Reductions).
474–482. Nine Duplicates of the above.
483, 484. Group of Orpheus and Eurydice. (Duplicates.) (Reduction.)
485–501. Seventeen Pieces. The whole Frieze of the Choragic Monument of Lysicrates, representing Bacchus transforming the Pirates into Dolphins.

502–504. Three Acanthus Leaves.
505. Flower.
506. Flower with Pine Cone.
507. Flower with Poppy-head.
508. Flower from Capital of Temple of the Sibyl Tivoli.
509. Egyptian Bas Relief.
510. " " Head of Cleopatra.
511. Egyptian Bas Relief.
512. Scroll from Choragic Monument.
513. Scroll from Tomb of the Scipios.
514. Roman Acroterium. Villa Pamphili Doria.
515. Renaissance Pilaster.

West side of Room.

516. Capital of Antæ. Minerva Polias.
517. Ionic Volute. Athens.
518. Horse's Head. Vatican.
519. Corinthian Capital. Modern.
520. The same. Pilaster Capital.
521. Horse. By Bailey.
422. Eagle. By Bailey.
523, 524. Acroteria from Parthenon. (Duplicates.)
525. Corner Capital from Erechtheum.
526, 527. Capital of Antæ, Erechtheum. (Duplicates.)
528. Architrave and Door Cap. Erechtheum.
529. Support of Table. Pompeii.
530. Renaissance Panel.
531. Another.
532. Leg to Table with Lion's Head and Foot. Capitol Museum.
Two Casts from Terra Cotta. Campana Collection.
533. Bacchante, Faun, and Infant Bacchus.
534. Castor and Pollux.
535, 536. Two Renaissance Medallions.
537. Colossal Head of David. Michael Angelo.
538. Cast of Greek Acroterium. Athens.

North side of Room.

539. Capital from Alhambra.
540. Moorish Panel.
541. Pilaster. Chateau de Gaillon.
Four Casts from Terra Cotta. Campana Collection.
542. Two Priestesses.
543. Scroll-work with Winged Victory.

544. Paris and Helen.
545. Helen and Menelaus.
546. Renaissance Bracket. Vatican.
547, 548. Two Modillions. Modern.
549. Console. Modern.
550. Honeysuckle Ornament.
551. Another, from the Erechtheum.
552. Another.

Eleven small Bas Reliefs.

553. Bacchanal and Panther.
554. Corybantes dancing. Vatican.
555. Faun dancing.
556. Mercury and part of a Group. Louvre.
557. Bacchus and Three Fauns.
558. Faun dancing.
559. Smaller figure, like No. 558.
560. Faun dancing. Villa Albani.
561. Pastoral Group.
562. Victory and Bull. Vatican.
563. Greek Inscription.
564. Large Alto Relievo, from end of the Vienna Sarcophagus.
565–572. Eight Acanthus Leaves. Modern.
573. Fragment of Cornice.
574, 575. Two Pilaster Panels.
576. Another.
577. Capital of Pilaster, same as No. 541.
578. Large Acanthus Leaf.
579, 580. Two Sets of small Rosettes. Modern.
581, 582. Two Guilloche Mouldings.
583. Set of Enriched Mouldings. Modern.
584. Profile Head. Full Size. Trajan's Column (?)
585. Head from Arch of Titus.
586. Another.
587. Two others.
588. Group from Trajan's Column. Four Soldiers.
589. Another. Soldier watering his Horse.
590. Upper part of Group. Five Soldiers going into battle.
591. " " Four Barbarian Captives.
592. " " Six Roman Citizens.
593–633. Forty-one Heads from Trajan's Column.

Soldiers, Citizens, Barbarians, Women and Horses.

634. Alto Relievo of the Battle of the Amazons, from a Sarcophagus at Vienna.

East side of Room. French Renaissance.

635, 636. Doric Capital and part of Rusticated Pilaster. Louvre.
637. Lion's Head, from the Hotel Carnavelet. Jean Goujon.
638. Pilaster Capital, with part of Enlablature.
639. Frieze, with Laurel Leaves. Chateau de Gaillon.
640. Key-stone, enriched. Chateau de Gaillon.
641. Lion's Head, from Nature. Bussy.
642–645. Four Capitals from Tomb of Louis XII. St. Denis.
646. Lioness' Head, from Nature. Bussy.
647. Door Knocker. Louis XIV.
648. Cartouche Frieze. Door of St. Maclou, Rouen.
649. Cartouche, with Cupid. Door of St. Maclou, Rouen.
650. Mask of Pan. Louvre.
651. Lion's Head.
652. Rosette. Modern.
653. Anatomical Figure by Michael Angelo.
654. Bracket.
655. Slave by Michael Angelo. Statuette.
656. Bracket with Cupid.
657. Head of Michael Angelo's Slave. Louvre.
658. The same reduced.
659–666. Six Pilaster Panels.
667, 668. Two Small Pilasters from Tomb of Louis XII. St. Denis.
669. Small Figure of a Lion. Rouillard.
670. Another, smaller.
671. Tiger. Rouillard.
672. *Écorché*, Horse. Bonheur.
673. " Man. Houdon.
674, 675. Two others. Coudron.
676. Mask. Pan.
677. Head. Nondescript. Modern.
678. Statuette. Milo of Crotona.
679. Bracket. (Duplicate of No. 654.)
680. Prisoner, by Michael Angelo. Statuette.
681. Bracket, with Cupid.
682. Mask of the Virgin, by Michael Angelo.
683. Statuette by Pradier. Woman carrying Water.
684. Bust by Pradier.
685–688. Four Pilasters from Tomb of Louis XII.
689. Figure from Tomb in the Church at Brou. The Virgin.
690. Another.
691. Another. St. Elisabeth.

692. Wing.
693. Bust of Diane de Poictiers. Jean Goujon.
694–697. Casts of Four small Vases.
698–702. Casts of Five Shells.
703. Mask.
704. Another.
705. Duplicate of No. 677.
706–708. Three small Cupids by Fiammingo.
709, 710. Two others, in Alto Relievo, larger, supporting a Cartouche.
Two Bas Reliefs from the Chateau d'Anet. Jean Goujon.
711. Angel with the Cross.
712. Angel with the Pillar.
713. Infant, from the lid of the Vase containing the Heart of Francis I. St. Denis. Jean Goujon.
714. Bas Relief from Tomb of Francis I. St. Denis.
715. Cupid from Court of the Louvre. Jean Goujon.
716, 717. Two heads by Fiammingo.
718. Small Capital.
719. Panel with Fleur-de-lys.
720. Panel with Crescent.
721, 722. Two Panels with Arabesque Griffins. St. Maur, near Paris.
723. Woman's Hand, from Nature.
724. Colossal Renaissance Hand.
725–728. The Four Seasons. Casts from the Terra Cotta Models of the Sculptures of the Fountain in the Rue de Grenelle. Bouchardon.
729, 730. Two Panels. Rome.
731. Head of John the Baptist. Donatello. Baptistry. Florence
732–743. Twelve Vases, Casts from the Hildesheim Treasure.
744–746. Three Fragments of Casts of Central American Sculpture.

Stained Glass.

First Screen.

Ruth in the Cornfield. Messrs. Morris & Co., London.
Head of David. Messrs. Lyon & Co., London.
Virgin and Child, in Canopy. Messrs. Lavers & Barraud. London.
Medallion, with Head of Milton. The same.
Two Panels of Quarry Work. The same.
One Panel of Mosaic Work, in Color. The same.
Two Panels with Flowers. Messrs. Heaton, Butler & Bayne, London.
Grisaille of Rolled Glass. The same.

Second Screen.

Two specimens of Grisaille work. Messrs. Cottier & Co., Glasgow.
Figure of Architecture. Messrs. Cook & Co., Boston.
Two grisaille panels, with medallions. The same.

Third Screen.

Two pieces consisting of fragments. Ancient English work.
Specimen of Heraldric work. Messrs. Heaton, Butler & Bayne.
Mosaic of Rolled glass. The same.
Grisaille of Rolled glass. The same.
Grisaille with small head. Messrs. Lavers & Barraud.
Two specimens of quarry-work. The same.

Fourth Screen.

Grisaille work. Messrs. Clayton & Bell, London.
Four Medallions with Angels. The same.
Five Medallions set in Grisaille work. Messrs. G. E. Cook & Co., London.
Two small panels.

TILES, TERRA COTTA, ETC.

Four large Specimens of Mosaic, Encaustic and Majolica tilework, by Messrs. Maw & Co. Broseley.
Two Hundred other Tiles. The same.
Six Tiles, illustrating Æsop's Fables. Messrs. G. E. Cook & Co., Lond.
Four of Painting and the Graces. The same.
Four pieces of Painted Tile Work. Messrs. Simpson & Co.
One Hundred Neapolitan Tiles.
Sixteen Ancient Tiles from Chapter House, Salisbury.
Twenty-four Modern Reproductions of Pompeiian Vases.
Three Modern Neapolitan Cups.
Seventeen small Copies of Statuary in Terra Cotta.
Two Specimens of Salviati's Venetian Mosaic.

MODELS.

Models of the Five Orders of Vignola, with Entablatures and Pedestals, by Brucciani.
Five Models belonging to the Boston Athenæum.
The Unitarian Church at Baltimore, showing Dome and Pendentives.
The Parthenon.
Shakespeare's House at Stratford.
Two smaller Models.
Model of a Dwelling House.

Three Models in Cork.
The Temple of Neptune at Poestum.
The Temple of the Sibyl at Tivoli.
An Etruscan Tomb.
Two Models of Window Finish.
Model of Door, and Door Finish.
Twenty Models of Joinery, published by the Frères Chrétiens.
Six Models of Framing, " " "

MISCELLANEOUS ARTICLES.

Thirty-six specimens of Ornamental Woods.
Thirty-six Specimens of Italian and other Marbles.
Small specimen of Pompeian Decoration.
Fragment of Opus Reticulatum.
Fragments of Roman Bricks.
Fragment of Vaulting Stone from Salisbury Cathedral.
Three Specimens of Scotch Granite, polished.
Specimen of Béton Coignet.
Specimen of Ransome's Patent Stone.
Large Wooden Corinthian Capital from Brattle Street Church.
Console and Modillions from the same.

LECTURE DIAGRAMS.

1. Elementary Mouldings.
2. Proportions of the Five Orders.
3. " " Tuscan Order.
4. " " Doric Order.
5. " " Corinthian Order.
6. Origin of Doric Order.
7. The Roman Doric Order.
8. Another. "
9. The Greek Doric Order.
10. Another. "
11. The Roman Ionic Order.
12. The Greek Ionic Order.
13. Assyrian Bas Relief.
14. Persian Capitals.
15. Lycian Tomb.
16. Another.
17. Another.
8. Another.

19. Egyptian Capital. Colored.
20. Assyrian Ornament. "
21. Another.
22. Roman Vaulting.
23. Early Gothic Vaulting.
24. Lierne Vaulting. Oxford Cathedral.
25. Fan Vaulting. Peterborough Cathedral.
26–29. Four Diagrams of Gothic Vaulting. Plans.
30. Three Half-timbered Houses.
31. French Gothic Capital.
32. Gothic Mouldings.
33. Gothic Bases.
34. Architectural Map of Greece, with the Colonies.
35. " Map of Italy.
36. " Map of France.
37. " Map of England.
38–40. Three Diagrams of Curvilinear Perspective.
41. General Diagram of the Perspective of Planes.
42. " " " Perspective of Shadows.
43–70. Diagrams of the Frères Chrétiens.
71–76. Six Cartoons for the Stained Glass in the First Church. Messrs. Lavers & Barrand.
77–79. Three Cartoons for the Stained Glass in the First Church. Messrs. Heaton, Butler & Bayne.
80, 81. Two Cartoons for the Stained Glass in the First Church. Messrs. Lyon & Co. and Saunders & Co.

FOURTEEN PAINTED DIAGRAMS LOANED BY THE LOWELL INSTITUTE.

1. Elementary Lines.
2. Trusses.
3. Egyptian Capitals and Columns.
4. Façade of Temple of Apollinopolis Magna.
5. Section through the Parthenon.
6. St. Paul's, *extra muros*. Rome. Interior.
7. Salisbury Cathedral, from the S. W.
8. Gothic Doorway and Capitals.
9. St. Peter's. Rome.
10. Villa Capra, near Vicenza.
11. Pompeian Palace. Vicenza.
12. English Manor House.
13. Christ Church. Cambridge.
14. Trinity Church. New York.

SUMMARY OF THE COLLECTIONS OF THE DEPARTMENT OF ARCHITECTURE.

378 Books.
2240 Photographs.
465 Card Photographs.
660 Stereoscopic Views.
250 Glass Slides.
810 Drawings.
963 Prints and Lithographs.
77 Drawings from the Ecole des Beaux-Arts, etc.
746 Plaster Casts.
35 Specimens of Stained Glass.
32 Architectural Models.
95 Lecture Diagrams.
Also Tiles, Terra Cotta, and various miscellaneous articles.

ALUMNI OF THE INSTITUTE.

The degree is Bachelor of Science (S. B.) in the department of I, Civil and Topographical Engineering; II, Mechanical Engineering; III, Mining Engineering; IV, Architecture; V, Chemistry; VI, Metallurgy; VII, Natural History; VIII, Physics; IX, Science and Literature; X, Philosophy. Present residence and occupation are given, so far as known.

GRADUATES IN 1868.

Ellery C. Appleton, III, Allentown, Pa. Engineer for Lehigh Coal and Navigation Co.

Nelson W. Conant, III, Columbus, Indiana. Farmers' Bank.

Frank R. Firth, I, Deceased.

Eli Forbes, IX, Clinton, Mass. Chemist at Lancaster Mills.

Charles C. Gilman, III, Marshalltown, Iowa. Chief Engineer, Central Railroad of Iowa.

Charles E. Greene (A.M., Harv. Coll.), I, Ann Arbor, Mich. Professor of Civil Engineering, University of Mich.

Albert F. Hall, II, Charlestown, Mass. Draughtsman at G. F. Blake Manufacturing Co., Boston.

William E. Hoyt, I, Boston, Mass. Instructor in Civil Engineering and Stereotomy, Mass. Inst. Tech.

Robert H. Richards, III, Jamaica Plain, Mass. Professor of Mining Engineering, Mass. Inst. Tech.

Walter H. Sears, I, Plymouth, Mass. Civil and Hydraulic Engineer, Boston.

Charles A. Smith, I, St. Louis, Mo. Professor of Civil and Mechanical Engineering, Washington University.

Joseph Stone, I, Manchester, N. H., Agent Manchester Mills.

Bryant P. Tilden, III, Philipsburg, Montana. Practising Assayer.

James P. Tolman, III, Boston, Mass. Supt. Silver Lake Co. for manufacturing steam packing, etc.

GRADUATES IN 1869.

William H. Baker, Helena, Montana. Chief Draughtsman, Surveyor General's Office.

Howard A. Carson, I, Providence, R. I. Assistant Engineer, Providence Water Works.

J. Rayner Edmands, II, Boston, Mass. Practising Mechanical Engineer.

William R. Nichols, V, Boston, Mass. Professor of General Chemistry, Mass. Inst. Tech.

Channing Whitaker, II, Lowell, Mass. Professor of Mechanical Engineering, Mass. Inst. Tech.

Graduates in 1870.

Edward K. Clark, II, Boston, Mass. Assistant Engineer Mass. State Board of Health.

Charles R. Cross, IX, Jamaica Plain, Mass. Professor of Physics and Descriptive Astronomy, Mass. Inst. Tech.

Russell H. Curtis, I, Boston, Mass. Civil Engineer, 12 West St.

Charles W. Hinman, III, Boston, Mass. State Inspector of Gas and Gas-Meters.

Sampson D. Mason, I, Logansport, Indiana. Treasurer and Chief Engineer, Detroit, Eel River and Illinois R.R.

N. Frederic Merrill, V, Cambridgeport. Supt. of the Boston Works of the Boston and Colorado Smelting Co.

Theodore F. Tillinghast, I, New Bedford, Mass. Private business.

Edmund K. Turner, I, Marblehead, Mass. Civil Engineer, in employ of Fitchburg R.R.

Daniel W. Willard, II, Jamaica Plain, Mass. Sheep raising in Wyoming Territory.

L. F. J. Wrinkle, III, Virginia City, Nevada. Surveyor General's Office.

Graduates in 1871.

Foster E. L. Beal, I, Ames, Iowa. Professor of Civil Engineering, State Agricultural College.

Addison Connor, (A. B., Tufts Coll.), I, South Framingham, Mass. Boston Water Works.

Henry M. Cutler, I, San José, Cal. Not heard from.

Elmer Faunce, III, Kingston, Mass. Out of employment.

Edward H. Foote, I, Somerville, Mass. Practising Civil Engineer.

Frank L. Fuller, I, Grantville, Mass. Civil and Hydraulic Engineer, 7 Exchange Place, Boston.

Henry M. Howe (A. B., Harv. Coll.), III, Boston. Travelling in Europe on professional business.

Albert H. Howland (A. M., Amherst Coll.), I, Boston, Mass. Civil Engineer, 12 West St.

G. Russell Lincoln, III, Steel Works P. O., Pa. Chemist of Pennsylvania Steel Works.

William A. Pike, I, Orono, Maine. Professor of Civil and Mechanical Engineering, Maine State College.

George H. Pratt, V, South Boston, Mass. Supt. Bayside Alkali Works.

Edward W. Rollins, III, Golden, Colorado. Resident Engineer and Cashier Col. Central R.R. Co.

Walter W. Smith, II, Dayton, Ohio. Manufacturer of Steam Pumps and Hydraulic Machinery.

Charles F. Stone, III, Waltham, Mass. Student at Law.

Almarin Trowbridge, Jr., II, Charlestown, Mass. Unemployed.

Isaiah S. P. Weeks, I, Charlestown, Mass. Office of T. and J. Doane, Civil Engineers.

Randal Whittier, V, Boston, Mass. Instructor in Mathematics, Boston University.

Graduates in 1872.

Calvin Francis Allen, I, Providence, R. I. Assistant Engineer, Providence Water Works.

Benjamin E. Brewster, III. Not heard from.

William B. Dodge, I, Beverly, Mass. Engineer's Office, State Lunatic Asylum, Danvers, Mass.

Frederic A. Emmerton, V, Joliet, Ill. Chemist of Joliet Iron and Steel Co.

J. Amory Herrick, V, Nashua, N. H. Supt. of Steel department of Nashua Iron and Steel Co.

James M. Hodge, III, New York. Assistant Engineer Erie Railway.

Bradford H. Locke, III, Central City, Colorado. Mining Engineer and U. S. Deputy Surveyor.

Charles S. Minot, V, Germany. Student of Natural History.

Walter Shepard (A. B., Harv. Coll.), I, Harrison Sq. Assistant Engineer Boston and Albany R. R.

Richard S. Soule (A. B., Harv. Coll.), II, Altoona, Pa. Mechanical Engineer's Office, Motive Power Department, Penn. R.R.

Clarence S. Ward, III, Boston, Mass. Lawyer, 35 Court St.

Graduates in 1873.

Amory Austin (A. B., Harv. Coll.), V, 40 Kilby St., Boston. Not heard from.

George W. Blodgett, I, Boston, Mass. Boston Water Works.

William E. Brotherton, I, Cincinnati, Ohio. Bookkeeper, Bank of Gilmore, Dunlap & Co.

Samuel A. Fabens, Jr., I, Deceased, March 14, 1875.

Samuel M. Felton, Jr., I, Pittsburg, Pa. Gen. Supt. Pittsburg, Cincinnati and St. Louis Railway Co.

Frederick L. Fisher, I, Medway, Mass. In business (Fisher & Taylor).

Clarence L. Howes (A. M., Amherst Coll.), I, Hanover, Mass. Not heard from.

Frederic Guild, Jr., IX, Boston, Mass. In Leather Business.

William D. Harris, I, Boston, Mass. Unemployed.

William A. Kimball, II, 38 Park Row, N. Y. N. Y. Belting and Packing Co.

William C. May, V, Boston, Mass. Student.

Frank B. Morse, I, Boston, Mass. Instructor of Drawing, M. I. T., and Warren Academy, Woburn.

George Phillipps, III. Not heard from.

Henry A. Phillips, IV, Chicago, Ill. Studying abroad.

Robert A. Shailer, I, Chicago, Ill. Engineer in employ of American Bridge Co.

Charles E. Stafford, III, Steel Works P. O., Penn. In charge of Open Hearth Steel department of Pa. Steel Works.

Ellen H. Swallow (Mrs. R. H. Richards) (A. M., Vassar Coll.), V, Jamaica Plain.

S. Everett Tinkham, I, Boston, Mass. City Engineer's Office.

Frank W. Very, V. Not heard from.

Webster Wells, I, Boston, Mass. Instructor in Mathematics and Descriptive Geometry, M. I. T.

Randal Whittier, S. B., I, Boston, Mass. Instructor in Mathematics, Boston University.

Francis H. Williams, V, Boston, Mass. Student, Harvard Medical School.

Louis F. Wood, V, Boston. Supt. Color Manufactory, Wellesley.

Graduates in 1874.

Herbert Barrows, I, Reading, Mass. Employed in Civil Engineering.

George H. Barrus, II, Reading, Mass. Engaged with Mr. George B. Dixwell upon experiments on cylinder condensation.

William T. Blunt, I, East Somerville, Mass. Draughtsman for Boston Harbor Commission.

George E. Doane, I, Middleboro, Mass. Observer U. S. Coast Survey.

William B. Dowse, IV, Boston, Mass. Not heard from.

Joseph S. Emerson, I, West Newton, Mass. Newton Water Works.

Elliot Holbrook, I, Providence, R. I. Teacher of Mechanical Drawing, etc., Warner's College.

Aechirau Hongma, I, Tokio, Japan. Government Engineer.

Charles P. Howard, I, Hartford, Ct. J. L. Howard & Co., Railway and Car Builders.

Frank H. Jackson, III, Boston, Mass. A. Jackson & Son, dealers in Fertilizers and Chemicals.

Willis H. Myrick, II. Died, Oct. 17, 1875.

Herbert B. Perkins, I, Monson, Mass. Teacher of Mathematics and Physics, Monson Academy.

Frank H. Pond, II, Dayton, Ohio. Assistant Supt. Brownell and Kielmeiér Manufacturing Co.

Edward S. Shaw, I, Cambridge, Mass. Pursuing advanced professional studies, partly at M. I. T.

Francis H. Silsbee, II, Manchester, N. H. Draughtsman at Manchester Mills.

Arthur W. Sweetser, I, So. Williamstown, Mass. Teacher in Greylock Institute.

Robert C. Ware, IX, Salem, Mass. Student in M. I. T.

Stephen H. Wilder, IX, Cincinnati, Ohio. In Rolling Mill.

GRADUATES IN 1875.

Samuel E. Allen, I, South Framingham, Mass. Boston Water Works.

James L. Arnott, X, Thompsonville. Ct. Not heard from.

Amos J. Boyden, IV, Foxborough, Mass. Draughtsman for Stone & Carpenter, Architects, Providence, R. I.

Moses D. Burnett, III, Syracuse, N. Y. Student in Medicine.

H. K. Burrison, I, East Boston, Mass. Draughtsman for Park Commissioners, and Sec. Boston and Northwestern R. R. Co.

Christopher A. Church, I, Woonsocket, R. I. Woonsocket Woolen Mills.

Frank S. Dodge, I, Beverly, Mass. In employ of Gen. Thom., U. S. Engineer, Portland, Me.

Edgar S. Dorr, I, Mt. Auburn, Mass. Unemployed.

William C. Edes, I, Bolton, Mass. Engineering work for Bureau of Statistics of Labor.

Charles W. Goodale, III, Boston, Mass. Boston and Colorado Smelting Works.

Edward A. W. Hammatt, I, Newton Centre, Mass. Unemployed.

Edward A. Handy, I, Boston, Mass. South Boston Flats Improvement.

James H. Head, II. Died August 18, 1875.

Thomas Hibbard, II, West Roxbury, Mass. Draughtsman, Atlantic Works, E. Boston.

William F. Huntington, I, Springfield, Mass. Bookkeeper, Chester Paper Co., Huntington, Mass.

Leonard P. Kinnicutt, V, Worcester, Mass. Studying in Europe.

J. Austin Knapp, II, Boston, Mass. Assistant in Mechanical Engineering, Inst. of Tech.

Wilfred Lewis, II, Phil., Pa. At William Sellers & Co., Machine Works.

Samuel J. Mixter, VIII, Boston, Mass. Student, Harv. Medical School.

Benjamin A. Oxnard, III, Brooklyn, N. Y. Assistant Supt. and Chemist Fulton Sugar Refinery.

Thomas D. Plimpton, II, Walpole, Mass. Student at Law.

William A. Prentiss, IX, Holyoke, Mass. Wire Manufacturing.

Francis T. Sargent, II, Malden, Mass. Assistant in Mechanical Engineering, Mass. Inst. Tech.

William H. Shockley, III, New Bedford, Mass. Resident Graduate Mass. Inst. Tech.

James B. Stanwood, II, Cincinnati, Ohio. Apprentice in R. R. Machine Shop.

H. L. J. Warren, III, Ore Knob, Ash Co., N. C. Metallurgist, Ore Knob Copper Co.

William R. Webster, III, Coshocton, Ohio. Coal Inspector for the Pittsburgh, Cincinnati and St. Louis Railway Co.

William F. Sargent, I, Sargentville, Maine. Unemployed.

LIST OF MEMBERS

OF THE

SOCIETY OF ARTS

OF THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,

SEPTEMBER 30, 1875.

HONORARY MEMBER.

* Prof. Daniel Treadwell, Cambridge, Mass.

LIFE MEMBERS.

Allen, Stephen M. . Boston.
Amory, William . . "
Atkinson, Edward . "

Baker, William E. . "
*Bancroft, E. P. . "
*Beebe, James M. . "
Bigelow, E. B. . . "
Bowditch, J. I. . . "
Bowditch, Mrs. J. I. "
Brimmer, Martin . "
Browne, C. Allen . "
Bullard, W. S. . . "

Colby, Gardner . . "
Cummings, John . . Woburn.

Dalton, Chas. H. . Boston.
Davenport, Henry . "
Dupee, James A. . "

Edmands, J. Wiley . "
*Eldredge, E. H. . "
Emerson, George B. "
Endicott, Wm., Jr. . "

Fay, Joseph S. . . "
Fay, Mrs. Sarah S. . Boston.
Forbes, John M. . . "
Forbes, Robert B. . "
Foster, John . . . "

Gaffield, Thomas . . "
*Gardner, G. A. . . "
Gardner, John L. . "
Gookin, Samuel H. . "
*Grant, Michael . . "
Greenleaf, R. C. . . "
Grover, Wm. O. . . "

Hemenway, Mrs. M. "
Hoadley, J. C. . . Lawrence.
*Huntington, Ralph . Boston.

Johnson, Samuel. . "

Kidder, Henry P. . "
Kuhn, Geo. H. . . "

*Lawrence, James . "
Lee, Henry . . . "
Lee, John C. . . . "
* Lee, Thomas . . "

* Deceased.

Little, James L. . . Boston.
Lowell, John A. . . "
Lyman, Geo. W. . "

Matthews, Nathan . "
McGregor, James . "
Mudge, E. R. . . . "

Nichols, Lyman . . "
Norcross, Otis . . "

*Pierce, Carlos . . Canada.
Preston, Jonathan . Boston.
Pratt, Mrs. William . "
Pratt Miss . . . . "

Richardson, Geo. C. . "
*Richardson, J. B. . "
Rogers, Henry B. . "
Rogers, William B. . "
Ross, M. Denman . W. Roxbury.
Ross, Waldo O. . . "

Ruggles, S. P. . . Boston.
*Savage, James . . "
Sayles Henry . . "
Sayles, Mrs. Willard "
*Sears David . . "
Shaw, Mary S. . . "
*Skinner, Francis . "
*Stetson, Joshua . "

Thayer, Nathaniel . "
Thorndike, John H. . "
Tobey, Edward S. . "
*Turner, J. M. . . "

*Upton, George B. . "

Walcott, J. H. . . "
Wales, Geo. W. . . "
Wales, T. B. . . . "
Wales, Miss . . . "
*Whitney, Joseph . "

ASSOCIATE MEMBERS.

Adams, James . . Charlestown.
Ames, Isaac . . . Boston.
Amory, T. C. . . . "
Anderson, Luther W. Quincy.
Appleton, Thos. G. . Boston.
Atkinson, Chas. F. . "
Atkinson, Wm. P. . "
Atwood, Nat'lh E. . Provincet'n.
Austin, Edward . . Boston.

Barber, Lyman L. . Charlestown.
Barnard, James M. . Boston.
Batchelder, John M. Cambridge.
Beal, James H. . . Boston.
Bender, Richard W. "
Bigelow, A. O. . . "
Bigelow, Jacob . . "
Bishop, Chas. J. . . "
Blaney, Henry . . "
Bôcher, Ferdinand . "
Bolles, M. Shepard . "
Bond, George W. . W. Roxbury.
Bond, W. S. . . . "
Boott, William . . Boston.
Bourne, William . . "

Bouvé, T. T. . . . Boston.
Bowditch, Ernest W. Brookline.
Bowditch, Wm. I. . "
Browne, Causten . . Boston.
Buckingham, C. E. . "

Cabot, Edward C. . "
Cabot, Samuel . . "
Carey, A. C. . . . "
Carpenter, Geo. O. . "
Carruth, Charles . "
Clapp, Wm. W. . . "
Clarke, E. H. . . "
Clinch, John M. . . "
Cummings, Nath'l . "
Curtis, Frederick . "

Dana, Edward A. . "
Danforth, I. W. . . "
Danforth, James H. . "
Davies, Daniel . . "
Davis, Barnabas . . "
Davis, F. J. . . . Waltham.
Delano, Jos. C . . New Bedford.
Denny, Henry G. . Boston.

Dewson, F. A. . . Boston.
Dix, John H. . . . "
Dixwell, J. J. . . . "
Doane, Thomas . . "
Dresser, Jacob A. . "
Dunklee, B. W. . . "

Eastman, Ambrose . "
Eliot, Charles W. . Cambridge.

Farley, Noah W. . Boston.
Farmer, Moses G. . "
Fitch, Jonas . . . "
Flint, Charles L. . "
Forbes, Franklin . Clinton.
Francis, James B. . Lowell.
Fuller, H. Weld . . Boston.
Fuller, Horace W. . "

Gardner, James B. . "
Gibbens, Joseph M. . "
Grandgent, L. H. . "
Guild, Chester . . "
Guild, Henry . . "

Hall, Andrew T. . "
Hall, Thomas . . . "
Hamblet, James . . "
Haven, Franklin. . "
Hayes, S. Dana . . "
Heard, John T. . . "
Henck, John B. . . Brookline.
Henshaw, John A. . Cambridge.
Hewins, Edmund H. Boston.
Hilton, William . . "
Holmes, O. W. . . "
Homans, C. D. . . "
Houghton, Charles . "
Hubbard, Charles T. "
Hyde, George B. . "
Hyde, Henry D. . "

Jackson, J. B. S. . "
Jasper, Gustavus A. . "
Jenks, Lewis E. . . "

Kehew, John . . . "
Kneeland, Samuel . "

Lamson, Chas. D. . "
Langley, H. P. . . "
Lanza, Gaetano . . "
Lawrence, A. A. . "
Lee, Francis L. . . Boston.
Lee, Thomas J. . . "
Leuchars, R. B. . . "
Lewis, Charles W. . Charlestown.
Lewis, Wm. K. . . Boston.
Lincoln, F. W. . . "
Little, James L., Jr. "
Little, John M. . . "
Lothrop, Sam'l K. . "
Lowe, N. M. . . . "
Lowell, John . . . "
Lyman, Theodore . Brookline.

Mansfield, A. K. . . Boston.
Markoe, G. F. H. . "
Marshall, H. N. F. . "
Mason, Robert M. . "
May, F. W. G. . . Dorchester.
May, John J. . . . "
McBurney, Charles . Boston.
McMurtrie, Horace . "
McPherson, W. J. . "
Merrill, N. F. . . . Cambridgep't.
Montgomery, Hugh . Boston.
Moore, Alex. . . . "
Morse, John T. . . "
Morse, Samuel T. . "
Munroe, William . "

Nichols, James R. . Haverhill.
Norton, Jacob . . Boston.

Ordway, John M. . W. Roxbury.

Page, Edward . . Boston.
Page, W. H. . . . "
Parsons, Wm. . . "
Paul, J. F. . . . . "
Peabody, O. W. . . "
Perry, O. H. . . . "
Philbrick, Edward S. "
Philbrick, John D. . "
Pickering, E. C. . . "
Pickering, H. W. . "
Plumer, Avery . . "
Pope, Edward E. . "
Prang, Louis . . . "
Pratt, George W. . "
Pratt, T. Willis . . "
Putnam, J. P. . . . "

Quincy, Edmund . Dedham.
Quincy, Josiah . . Boston.

Revere, Joseph W.	Boston.
Rice, Alexander H.	"
Richards, R. H.	"
Ritchie, E. S.	Brookline.
Robbins, James M.	Milton.
Robinson, J. R.	Boston.
Rotch, Benj. S.	"
Royce, H. A.	"
Ruggles, John	"
Runkle, John D.	Brookline.
Russell, LeBaron	Boston.
Salisbury, D. Waldo	"
Sawyer, Edward	Newton.
Sawyer, Timothy T.	Charlestown.
Sears, Philip H.	Boston.
Shedd, J. Herbert	"
Sherwin, Thos.	Dedham.
Shimmin, Chas. F.	Boston.
Shurtleff, A. M.	"
Sinclair, Alex. D.	"
Smith, Chauncy	Cambridge.
Snow, S. T.	Boston.
Sonrel, Antoine	Winchester.
Sprague, Chas. J.	Boston.
Stackpole, G. W.	"
Stevens, Benj. F.	"
Stimpson, Fred. E.	"
Storer, Frank H.	"
Strater, Herman, Jr.	"
Sturgis, John H.	"
Sullivan, Richard	"
Thompson, Wm. H.	Boston.
Trowbridge, John	Cambridge.
Tufts, John W.	Boston.
Tuxbury, Geo. W.	"
Upham, J. B.	"
Urbino, S. R.	"
Walworth, J. J.	"
Ware, Chas. E.	"
Ware, Wm. R.	"
Warren, Cyrus M.	Brookline.
Warren, Geo. W.	Boston.
Warren, Joseph H.	"
Warren, Sam'l D.	"
Waters, C. H.	Clinton.
Watson, R. S.	Milton.
Watson, Wm.	Boston.
Weston, David M.	"
Whipple, Edwin P.	"
Whitaker, Channing	Lowell.
Whitman, Herbert T.	Boston.
Whitmore, Wm. H.	"
Whiton, David	"
Wilder, Marshall P.	Dorchester.
Williams, H. W.	Boston.
Winthrop, Robert C.	"
Wright, John H.	"
Wyman, Morrill	Cambridge.
Zalinski, E. L.	Boston.

PREPARATION FOR ADMISSION.

Preparation for Admission.—In order to afford to instructors and others a somewhat definite idea of the requirements for admission to the school, the following statements and suggestions are made.

Arithmetic. — The candidate will be expected to be familiar with the ordinary operations of arithmetic in both simple and compound numbers, with common and decimal fractions, with the computation of interest, etc. In the metric system a general knowledge will be required of the origin and advantages of the system, of the manner of designating the multiples and divisions of the units of length, capacity, etc., and especially of the relation existing between the measures of weight and those of length and capacity. Ability to perform ordinary arithmetical problems in the metric system will be required, but no stress will be laid upon the conversion of the ordinary United States weights and measures into the corresponding values of the metric system; as, however, the metric weights and measures are used constantly immediately on the students' entering upon the work of the school, practical familiarity with them is very desirable.

Geography. — A good elementary knowledge of the motions of the earth, of the mathematical measurements and divisions of its surface, and of the outlines of physical and political geography is required. The candidate for admission should be able to correctly define any of the principal physical features of the earth's surface, such as peninsulas, gulfs, etc.; he should be able to locate and describe the chief natural and political divisions, and the most important mountain chains, river-systems, etc. A more complete knowledge of North America and Europe is expected than of the other continents, but minute details and statistics, such as the lengths of rivers and heights of mountains, are not required. Practice in free-hand map draw-

ing from memory is earnestly recommended, and proficiency in the art will receive the merit it so justly deserves.

The following may serve as an illustrative example of the nature of the questions the candidate is expected to answer.

1. Define latitude — North Temperate zone — mountain — ocean — border-sea — kingdom — republic — state — town.
2. Draw rapidly an outline map of South America, making it as complete as time will permit.
3. Draw a map of the State, Province, or country where you reside, representing as many of its features as you conveniently can.
4. In what latitude is New York city? What countries, cities, or seas of the Eastern World have nearly the same latitude?
5. Give a geographical description of Italy. Also one of the State of New York.
6. In what sections of the United States is cotton an important agricultural product?
7. To which race do the Japanese belong? Give some idea of the national character of the French.
8. What is the capital of Kansas? of Georgia? of Holland?
9. Give the boundaries of the States of Kentucky, California and Connecticut. Where is Mount Shasta? Name the great mountain regions of the globe.

English Grammar. — In English Grammar, candidates must be able to distinguish at sight between the several parts of speech, and to give the proper inflections of nouns, pronouns, adjectives, and verbs; especially the comparison of irregular adjectives, the principal parts of irregular verbs, and, in all verbs, the exact forms corresponding to the distinctions in mood and in tense. Particular attention should be paid, in preparing for the Institute, to distinguishing prepositions from conjunctions, and subordinate conjunctions from co-ordinate. The same is true in regard to demonstrative, indefinite, relative, and interrogative pronouns.

Candidates must also know how to classify terms (whether single words or phrases) into substantives and attributives, and must be familiar with the subdivisions of substantives into sin-

gulars, generals, and universals. They must have a good degree of skill in separating sentences into subject, copula, and predicate; and, in case these terms are complex, must know how to separate them into base and determinant, and how to tell whether the determinant *changes* the meaning of the base or merely *unfolds* it. In case the meaning is *changed*, they must be able to show whether the modifiers are objective, or signify some other relation, *e. g.*, time, place, cause, comparison or possession.

In regard to all the foregoing matters, teachers should aim to secure *practical skill in applying the distinctions to examples*, rather than a mere knowledge of their definitions. *In the examination for admission, this skill in practice will be made the vital point.*

[The less familiar of the foregoing distinctions may be defined as follows: —

A *singular* term is one that denotes absolutely but one object of a kind, whether that object be a solitary individual or a solitary group of individuals. A singular may therefore be either a proper or a collective noun, or any phrase equivalent to either. For example, Julius Cæsar, London, this city, the committee, the cities of the plain.

A *general* term is one that denotes more than one object of a kind, but less than all the possible members of it. It may do this either (1) by naming any *one* of them *indeterminately* (as *man, a man, some man or other*), or (2) by naming several *distributively* (as *men, some men, five men*), or (3) by naming *all* within certain limits — all the *actual* cases as contrasted with all *possible* cases (as *men*, in the sense of *most men* or *all men hitherto* or *all men now living*). For example, cities, all the continents, the continents.

A *universal* term is one that denotes absolutely all the objects of a kind, *i. e.*, all *possible*, future as well as present and past. For example, truth, the true, duty, the beautiful, space, time, causality, all triangles, every circle.

The *base* of a complex term is that word, or combination of words, in it that expresses the starting-point of the thought denoted by the whole term. For example, man, in the term "good man"; good man, in the term "every good man."

The *determinant* of a complex term is the word, or combina-

tion of words, added to the base, and characterizing it. For example, good, in the term "good man"; every, in "every good man"; of all times, in "the wise and good of all times."

All the other distinctions mentioned above, are to be taken according to the customary usage in treatises on grammar.]

English and American History. — The examination in this subject will be upon the period of the American Revolution beginning with the accession of George III.; and a better and more thorough knowledge of this portion of history—but rather of the causes of the revolution and the lives and characters of the chief actors than a minute acquaintance with the details of military transactions, will be expected than can be obtained from the mere study of the names and dates of a school compendium.

Rhetoric. — In Rhetoric the examination will be confined to those parts of any school manual which give the rules for the construction of sentences and treat of the qualities which characterize a good style. The object of this examination will be to test the candidate's ability to write good English, and as a preparation for it, *practice* in English composition is strongly recommended in preference to the study of the remaining portions of the Rhetorics.

French. — The essential part of the *French requirement for admission* to the school is the grammar, or knowledge of the forms and structure of the language, and we would offer with this in view the following suggestions in regard to the preparatory study.

a. The *verb* should be made the main study, and the other parts of speech in proportion to the closeness of their relation to the same.

b. The *regular conjugations* should be mastered before taking up the study of the irregular ones, and so of the other regular forms and usages as compared with the exceptions and idioms.

c. Next to the verb in importance comes the pronoun, particularly the *personal pronoun*, the form and value of which depends mainly upon its relation to the verb, whether as sub-

ject, direct object, *dative*, or as connected by a preposition, a careful analysis alone eliciting the specific relation in each case; hence the importance of a thorough analytical training.

d. The amount of *reading matter* is not so much for the sake of the knowledge of words and its intrinsic value, as to afford a sufficiently wide field for exercise in analysis and the discrimination of forms, quality being more important than quantity, and accuracy essential.

e. In regard to pronunciation, it is more important that the student have an accurate conception of the nasal, e, é, è, and u sounds, the connection of words, and the division into syllables, than greater fluency with less accuracy.

English Literature.—The examination will be upon the literary history of the latter part of the Eighteenth and the early part of the Nineteenth century. The candidate will be expected to be familiar with the names and general character of the leading writers of that period, and to show an acquaintance, from actual reading, with some portion of its literature.

Algebra.—Besides possessing ability to perform ordinary algebraic operations, the candidate must be able to solve simple and quadratic equations with two or more unknown quantities, and must understand theoretically and practically the involution of algebraic expressions, the extraction of square and cube root, fractional and negative exponents and radicals.

Besides readiness in the solution of examples, it is important that the student should be well drilled in the principles involved and be able to state them clearly and concisely. For example, besides ability to solve readily a quadratic equation, he should also be familiar with the few fundamental properties of the quadratic roots, and particularly with the conditions upon which equal and imaginary roots depend.

While the theory of logarithms is not at present required, it is extremely desirable that students should early become familiar with their use, and teachers are earnestly advised to put into their hands Professor J. M. Peirce's four place tables, or Bowditch's five place tables, or Bremiker's six or seven place tables, and show them how much time familiarity with their use will

soon enable them to gain in all numerical work. Nor need this be a blind use; for as soon as the student understands what an exponent is, and that the multiplication, division, the involution and the evolution of numbers are affected by the addition, subtraction, multiplication and division of exponents, he has only to learn that the exponent is a logarithm, to use the tables intelligently.

Geometry. — In plane and solid (including spherical) geometry, the amount contained in the standard text-books on the subject will be required; and care should be taken to apply all propositions, which find frequent use, to numerical examples.

LOWELL FREE COURSES OF INSTRUCTION.

1865–1866.

1. *Elementary Mathematics.* Eighteen lectures, by Professor Runkle.
2. *Descriptive Geometry.* Eighteen lectures, by Professor Watson.
3. *Chemistry of the Non-metallic Elements.* Eighteen lectures, by Professor Storer.
4. *The Metals.* Eighteen lectures, by Professor Eliot.
5. *English Language and its Literature.* Eighteen lectures, by Professor Atkinson.
6. *French.* Eighteen readings, by Professor Bôcher.

1866–1867.

1. *Chemical Manipulations.* Thirty practical lessons, by Professors Storer and Eliot.
2. *Mathematics.* Eighteen lessons, by Professor Runkle.
3. *Navigation and Nautical Astronomy.* Eighteen lessons, by Professor Osborne.
4. *Elementary French.* Eighteen lessons, by Professor Bôcher.
5. *Grammar, Rhetoric and Composition.* Ten lessons, by Professor Atkinson.

1867–1868.

1. *Geometry and Trigonometry.* Eighteen lessons, by Professor Osborne.
2. *Calculus.* Eighteen lessons, by Professor Runkle.
3. *Elementary German.* Eighteen lessons, by Instructor Krauss.
4. *Chemical Manipulations.* Thirty lessons, by Professor Storer.
5. *Natural History.* Ten lessons, by Professor Kneeland.
6. *Languages and General Grammar.* Ten lessons, by Professor Atkinson.

1868–1869.

1. *Qualitative Chemical Analysis.* Thirty lessons, by Professors Eliot and Storer.
2. *Mining, and the Mineral Resources and Deposits of the United States.* Eighteen lectures, by Professor Rockwell.
3. *English History and Literature.* Eighteen lectures, by Professor Atkinson.
4. *Comparative Physiology and the Laws of Life.* Eighteen lectures, by Dr. Kneeland.
5. *French.* Eighteen lessons, by Professor Bôcher.

[illegible]

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]
6. [illegible]

1873 1874.

1. *Elementary Physics.* Eighteen lectures by Professor [illegible]
2. *Physiology and Hygiene.* Eighteen lectures by Professor Rowland.
3. *Descriptive Geometry, Spherical Projections, Shades and Shadows, and Isometrical Drawing.* Fifteen lectures, by Professor Wood.
4. *General Chemistry.* Fifteen laboratory lectures, by Assistant Professors Richards and Nichols.
5. *Qualitative Analysis.* Fifteen laboratory exercises, by Assistant Professors Nichols and Richards.
6. *Modern History and Literature.* Eighteen lectures, by Professor Atkinson.

1871 1872.

1. *English Writers of the 18th and 19th Centuries.* Ten lectures, by Professor Atkinson.
2. *Progressive Development of Life on the Geological Type.* Eighteen lectures, by Professor Rowland.
3. *Elementary German.* Eighteen lessons, by Instructor [illegible]
4. *Elementary French.* Eighteen lessons, by Instructor [illegible]
5. *Elementary Chemistry.* Twenty lectures, by Professors Richards and Nichols.
6. *Experimental Chemistry.* Twenty four laboratory exercises, by Professors Richards and Nichols.
7. *Experimental Physics.* Twenty four laboratory exercises, by Professor Pickering.

1872 1873.

1. *Chemical and Physical Geology.* Eighteen lectures, by Professors [illegible]
2. *Engineering Mechanics.* Eighteen lectures, by Professor [illegible]
3. *Modern History.* Ten lectures, by Professor [illegible]

4. *Logic with special reference to its connection with English Analysis.* Ten lectures, by Professor Howison.

5. *Laws of Life and Health.* Ten lectures, by Professor Kneeland.

6. *Systematized French Pronunciation, French Conjugation, Idiomatic French.* Eighteen lectures, by Instructor Lévy.

7. *Translation of Lessing's Nathan der Weise, with a Philological and Critical Commentary.* Eighteen lectures, by Instructor Krauss.

8. *Elements of Descriptive Geometry.* Eighteen lectures, by Instructor Lanza.

9. *Machine Drawing.* Eighteen lessons, by Professor Schubert.

1873–1874.

1. *Logic. An Examination of the system of J. S. Mill.* Eighteen lectures, by Professor Howison.

2. *Sound.* Eighteen lectures, by Professor Cross.

3. *Machine Drawing* for advanced students. Twenty-four exercises, by Instructor Schubert.

4. *Elementary Descriptive Geometry.* Eighteen lectures, by Professor Lanza.

5. *Chemistry: Qualitative Analysis.* Twenty-four laboratory exercises, by Professor Nichols.

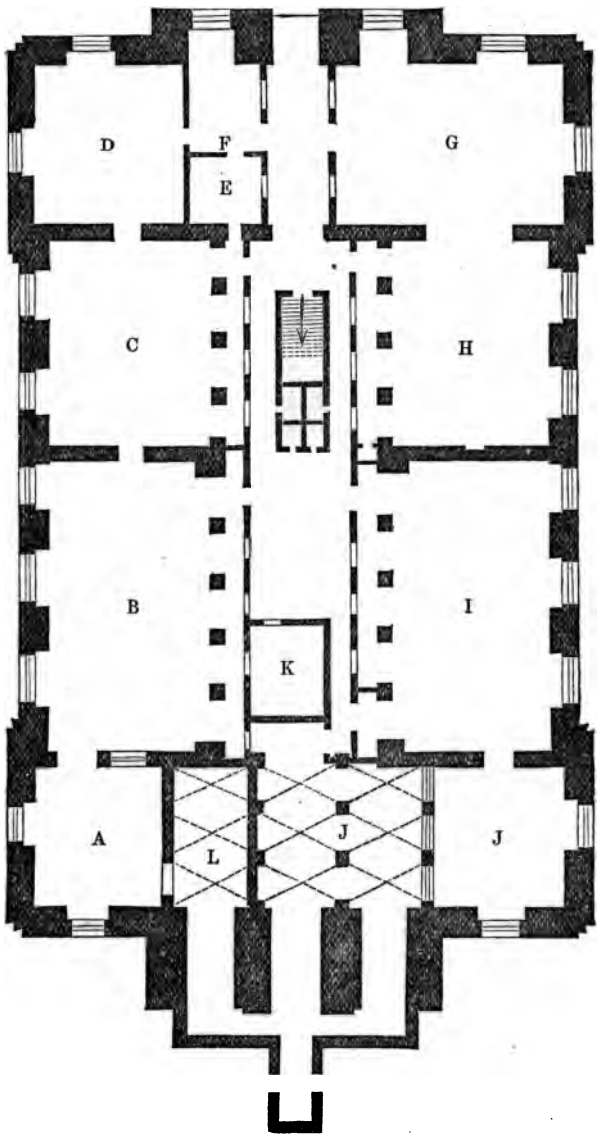
6. *Architectural History and Design.* Eighteen lectures, by Professor Ware.

7. *Elementary German.* Eighteen lessons, by Instructor Krauss.

1874–1875.

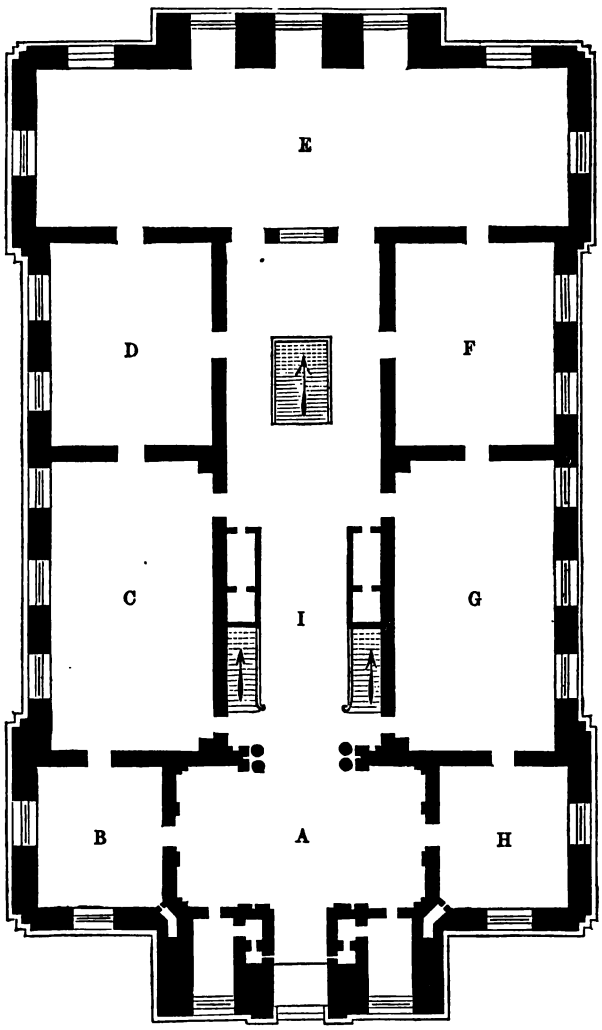
For reports upon the Courses of 1874–75, see pp. 94–104.

BASEMENT FLOOR.



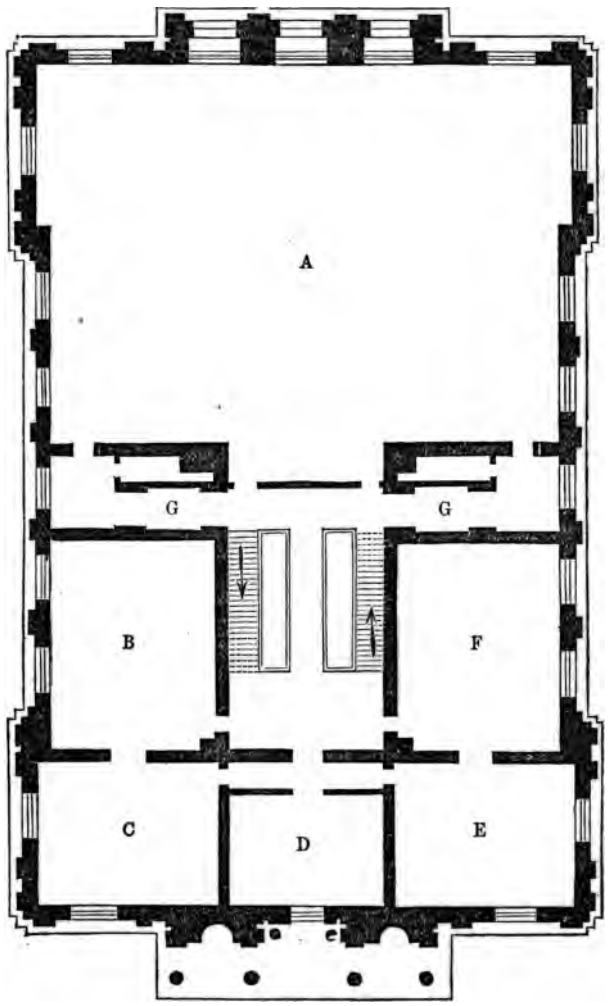
A. Professors' Chemical Laboratory, 25′ 0″ by 22′ 11″.
B. General and Qualitative Chemical Laboratory, 49′ 7″ by 34′ 0″.
C. Quantitative Chemical Laboratory, 35′ 8″ by 34′ 0″.
D. Quantitative Chemical Laboratory, 26′ 4″ by 24′ 0″.
E. Balance Room, 8′ by 13′.
F. Professor Wing's Private Laboratory, 16′ 0″ by 13′ 0″.
G. Mining Laboratory, 40′ 2″ by 27′ 10″.
H. Metallurgical Laboratory, 35′ 8″ by 34′ 0″.
I. Chemical Lecture Room, 49′ 7″ by 34′ 0″.
J. J. Mechanical Engineers' Laboratory, 25′ 0″ by 69′ 1″.
K. Daily Chemical Supply Room, 14′ 6″ by 12′ 0″.
L. Boiler Room, 15′ by 25′ 0″.

FIRST STORY FLOOR.



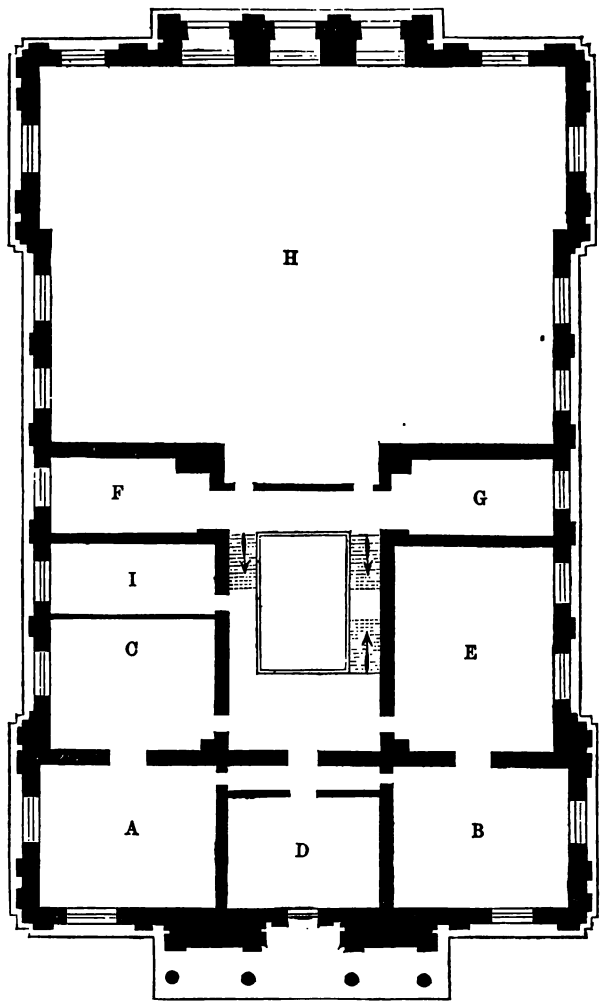
A. Entrance Hall, 42′ 2″ by 25′ 0″.
B. President's Office, 25′ 0″ by 22′ 11″.
C. Physical Lecture Room, 49′ 7″ by 28′ 3″.
D. Physical Laboratory and Apparatus Room, 35′ 8″ by 28′ 3″.
E. Physical Laboratory and Apparatus Room, 92′ 0″ by 27′ 10″.
F. Geological Lecture Room, 35′ 8″ by 28′ 3″.
G. Society of Arts Room, 49′ 7″ by 28′ 3″.
H. Secretary's Office, 25′ 0″ by 22′ 11″.
I. Stairway Hall, 87′ 3″ by 26′ 10″.

SECOND STORY FLOOR.



A. Huntington Hall, 92′ 0″ by 65′ 5″.
B. Mathematical Lecture Room, 34′ 9″ by 28′ 3″.
C. Civil Engineering Lecture Room, 32′ 2″ by 25′ 0″.
D. Modern Language Lecture Room, 26′ 2″ by 20′ 6″.
E. English Lecture Room, 32′ 2″ by 25′ 0″.
F. Mathematical and Astronomical Lecture Room, 34′ 9″ by 28′ 3″.
G. G. Passageways to Huntington Hall.

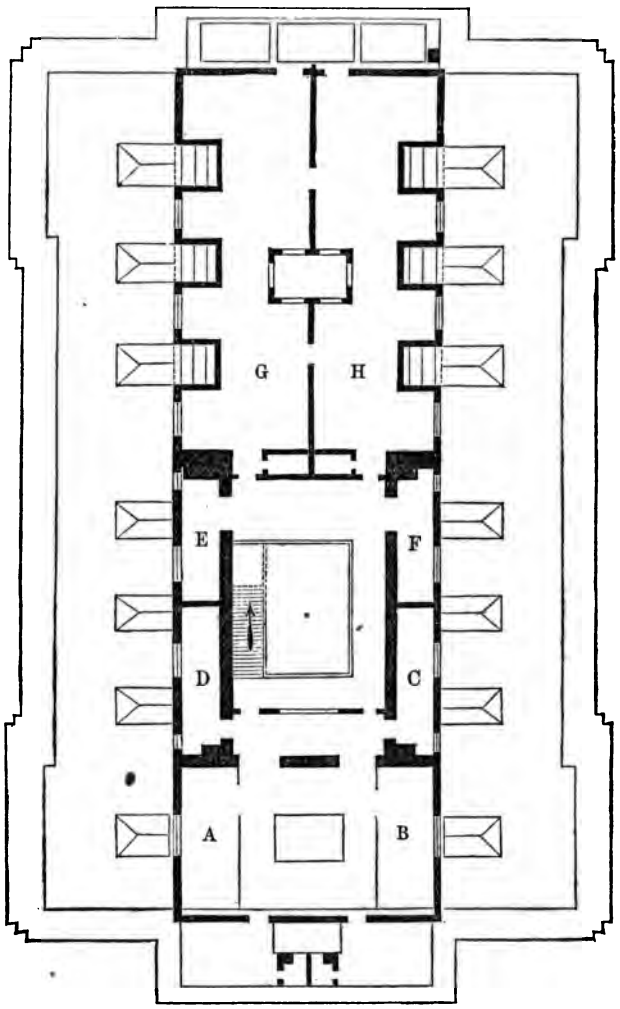
HALF STORY FLOOR.



A. Architectural Museum, 32′ 2″ by 25′ 0″.
B. Architectural Library and Study Room, 32′ 2″ by 25′ 0″.
C. Architectural Museum, 28′ 3″ by 20′ 9″.
D. Natural History Lecture Room, 26′ 2″ by 20′ 6″.
E. Prof. Richards' Lecture Room, 34′ 9″ by 28′ 3″.
F. Prof. Atkinson's Study, 28′ 3″ by 14′ 2″.
G. Prof. Hunt's Study, 28′ 3″ by 14′ 2″.
H. Huntington Hall.
I. Prof. Howison's Study, 28′ 3″ by 14′.

A. [illegible]
B B. [illegible]
C. [illegible]
D. [illegible]
E. [illegible]
F. [illegible]
G. [illegible]
H. [illegible]
I I I. [illegible]

FOURTH STORY FLOOR.



A. Prof. Lanza's and Prof. Whitaker's Study, 24′ 5″ by 11′ 6″.
B. Prof. Henck's Study, 24′ 5″ by 11′ 6″.
C. Prof. Osborne's Study, 24′ 9″ by 7′ 6″.
D. Prof. Richards's and Prof. Nichols's Study, 28′ 0″ by 7′ 6″.
E. Instructor Hoyt's Study, 21′ 6″ by 7′ 6″.
F. Prof. Ware's Study, 24′ 9″ by 7′ 6″.
G. Architects' Drawing Room, 65′ 5″ by 21′ 10″.
H. Lowell School of Design, 65′ 5″ by 21′ 10″.

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REPORTS

OF THE

PRESIDENT, SECRETARY,

AND

DEPARTMENTS.

1871-72.

BOSTON:
PRESS OF A. A. KINGMAN.
1872.

MASSACHUSETTS INSTITUTE

OF

TECHNOLOGY.

PRESIDENT'S REPORT.

To the Corporation of the Institute.

GENTLEMEN:—Your attention is respectfully invited to the accompanying reports, as carefully prepared statements of the condition of the departments to which they relate, and leaving but little to be said in addition.

Since the report of the department of Mining and Metallurgy was put in type, Mr. Samuel Bachelder, of Cambridge, has presentedto the Institute his very ingenious dynamometer, which accurately weighs all the power transmitted through it. This will enable the department to keep an exact record of all the power used in the mining and metallurgcial laboratory in running all or any of the machines in use. We have also received a Blake crusher, size 3″ by 5″, and a 12 inch Whelpley and Storer dry pulverizer. The new smelting and blast furnaces have been fully designed by Prof. Ordway, and their construction begun.

Our thanks are due to H. J. Booth & Co., of the Union Iron Works, San Francisco, California, for a very large and generous reduction in the price of the machinery furnished by them; and it is but justice to I. M. Scott, Esq., of that firm,

who designed and built the five-stamp battery now in our laboratory, expressly for the Institute, to say that it is complete in all its parts, and gives entire satisfaction. Our thanks are also due to Col. J. J. Storer, for a large reduction in the price of his pulverizer.

Prof. Henck and a party of fifteen students in the department of Civil Engineering left Boston, on Thursday, the 6th of June, for the purpose of making a systematic study of the great rail-road bridges over the Hudson, Ohio, Mississippi and Missouri rivers. On the way out each bridge will be examined by the whole party under Prof. Henck's direction, and a particular bridge assigned to each student, which he will be required to study in greater detail on his return; obtaining sketches and measurements of foundations and superstructure, and all the data for making a full report, accompanied with drawings of plan, elevation, sections, and all details necessary for the construction. We hope to do this summer for bridge construction, what was done the last for Mining Engineering and Metallurgy. It is proposed, hereafter, to make bridge construction a very important element in the course, and to this end it is earnestly recommended that models of all the important types of American bridges be supplied to the department as soon as possible.

We are well supplied with excellent field instruments, and the number is increased as fast as needed; but we have been, and still are, dependent upon the kindness of Prof. Peirce, Sup't. of the Coast Survey, for the use of a base-line measure, and a large altitude and azimuth instrument for triangulation, and for obtaining astronomical data for positions. It is most convenient for the department to use these instruments at the time when the subjects properly come in the course, and not when they can be best spared, if at all, by the Survey; and on this account it is very desirable that they be added to the collections of the department.

The work in the department of Drawing, both free-hand and mechanical, has upon the whole, been well maintained. Mr.

Schubert was absent last year for the purpose of study, and the break in the free-hand work, thus caused, has not been fully made up during the session just ended; but it is already evident that the department will be a great gainer in the end by the increased knowledge and appliances for instruction, which Mr. Schubert brought back as the fruit of his year's study in the celebrated art school of Nuremberg. The work in Descriptive Geometry and Stereotomy and the corresponding courses in Mechanical Drawing, will hereafter be under the same direction during the whole four years, which is expected to result in an improvement.

I am authorized by Hon. John Amory Lowell to announce that it is his intention to establish courses of instruction in the Institute in Designing as applied to the Industrial Arts.

These courses will be duly announced.

The Faculty of the School of the Institute has been increased during the past year by the appointment of Thomas Sterry Hunt as Professor of Geology, George H. Howison as Professor of Logic and the Philosophy of Science, and S. Edward Warren, as Professor of Descriptive Geometry, Stereotomy and Drawing. These gentlemen, eminent in their respective departments, will enter upon their duties with the new year.

At the recent entrance examinations, held June 3, and the following days, sixty-four applicants were admitted, sixty-two to the first year's class, and two to the second; an increase of thirteen over the corresponding examinations of last year. If the same proportional increase shall hold at the fall examinations the new class will largely exceed one hundred, and we shall be obliged to consider the question of a new building to meet the growing demands for space in which to properly carry on our work.

It gives me the greatest pleasure to be able to say that the most friendly and cordial relations continue to prevail between teachers and students, and that the past year's work in all departments has been of the most satisfactory character.

In accordance with your vote, the following brief sketch is appended for those who are interested in the origin and progress of the Institute in its several departments.

In the years 1858 and 59, an association of gentlemen residing in and near Boston, interested in the professional applications of science, and in the practical and fine arts, conceived the idea of securing the proper site on which to erect, in close proximity, such buildings as might be suitable and necessary for the purpose of the museums and collections of the Natural History Society, the Horticultural Society, and such others as might be formed representing the Industrial and Fine Arts, so as by their union and coöperation to constitute a comprehensive Museum, or Conservatory of Arts and Sciences.

With this view, after organizing as a "Committee of Associated Institutions," Hon. Marshall P. Wilder, Chairman, and Dr. Samuel Kneeland, Secretary, they petitioned the Legislature for a grant of land on the Back Bay, on which to erect buildings suitable for the proposed purposes.

At about the same time, Mr. William E. Baker had also suggested the desirableness of building up in some convenient location in Boston a Conservatory of Arts, and published some numbers of a Journal in advocacy and aid of the idea.

The time, however, seemed not yet to have come; the Legislature refused to make the grant of land, but the Committee, instead of being disheartened, redoubled their efforts.

About this time the matter was brought to the attention of Prof. William B. Rogers, whose deep interest in such subjects, and whose ability to aid in devising and consummating the proper plans to secure the desired ends, were well known. He prepared a memorial to the Legislature of 1860, which was adopted by the Committee. In this memorial we find the first suggestion of a School of Applied Science, in the plea for the early establishment of a "Comprehensive Polytechnic College," furnishing a "complete system of industrial education supplementary to the general training of the other institutions,

and fitted to equip its students with every scientific and technical principle applicable to the industrial pursuits of the age."

This, like the previous effort, failed to secure the favor of the Legislature, but it attracted attention to the growing importance of practical education, and led the way to the more definite scheme of organization which was developed in a Report by Prof. Rogers, and adopted by the Committee in the autumn of 1860. This Report, entitled "Objects and Plan of an Institute of Technology; including a Society of Arts, a Museum of Arts, and a School of Industrial Science," was read at a meeting of gentlemen interested in the establishment of an Institute of Technology, held at the rooms of the Board of Trade, October 5, 1860, and, on vote, was approved, and its publication recommended. The wide circulation of this able report, accompanied by an appeal to the public for coöperation and support, led to the calling of a meeting on Jan. 11, 1861, at Mercantile Hall, Summer St., "for the purpose of adopting measures preliminary to the organization of the Institute, and in furtherance of a petition to the Legislature for a charter, and a portion of the Back Bay lands."

The number of subscribers at this time amounted to 209.

The meeting was held at the appointed time; and after an exposition, by the Chairman, of the previous action and future purposes of the Committee, and interesting addresses by Prof. Peirce, Rev. Dr. Gannett, and others, in behalf of the Institute, a preliminary organization was established by adopting the following form of association, to which the names of those present were affixed: —

"We the subscribers, feeling a deep interest in promoting the Industrial Arts and Sciences as well as Practical Education, heartily approve the objects and plan of an Institute of Technology, embracing a Society of Arts, a Museum of Arts, and a School of Industrial Science, as set forth in the Report of the Committee; and we hereby associate ourselves for the purpose of endeavoring to organize and establish in the city of Boston such an Institution, under the title of 'The Massachusetts Institute of Technology,' whensoever we may be legally empowered and properly prepared to carry these objects into effect."

The following resolutions were then adopted:—

"*Resolved*, That a Committee of twenty, with power to increase their number, be appointed to represent the interests and objects of the Association, and to act generally in its behalf, until it shall be legally incorporated and regularly organized under the title, and according to the purposes, of the Massachusetts Institute of Technology.

"*Resolved*, That said Committee be instructed to use its best efforts, in co-operation with the Committee of Associated Institutions of Science and Arts, to obtain from the Legislature an Act of Incorporation of the Institute, and secure a grant of land on the Back Bay for its use, and for that of other institutions devoted to the Practical Sciences.

"*Resolved, further*, That this Committee be requested to frame a Constitution and By-laws for the government of said Institute in its several departments, and to submit the same to the consideration of this Association, whensoever we may be in readiness, and properly empowered, to organize formally as the Institute of Technology."

Subsequently, on motion, the Chairman of the meeting was added to the Committee, to act as its Chairman.

The members of this Committee are as follows:—

W. B. ROGERS, *Chairman*.

J. M. BEEBE.	J. B. FRANCIS.
E. S. TOBEY.	J. C. HOADLEY.
S. H. GOOKIN.	M. P. WILDER.
E. B. BIGELOW.	C. L. FLINT.
M. D. ROSS.	THOS. RICE.
J. D. PHILBRICK.	JOHN CHASE.
F. H. STORER.	J. P. ROBINSON.
J. D. RUNKLE.	F. W. LINCOLN, Jun.
C. H. DALTON.	THOS. ASPINWALL.
E. C. CABOT.	J. A. DUPEE.

This Committee, in coöperation with the Committee of Associated Institutions of Science and Arts, again applied to the Legislature for a charter and land, which was granted in an act approved April 10, 1861. This act made "William B. Rogers [and others named] a body corporate, by the name of the Massachusetts Institute of Technology, for the purpose of instituting and maintaining a Society of Arts, a Museum of Arts, and a School of Industrial Science, and aiding generally, by suitable means, the advancement, development and practical application of science in connection with arts, agriculture, manufactures and commerce."

It also granted one square of land bounded on the east and west by Berkeley and Clarendon Streets, and on the north and

south by Newbury and Boylston Streets, the easterly one-third to the Boston Society of Natural History, and the remaining two-thirds to the Institute of Technology, with the condition that neither corporation should cover more than one-third of the land granted to it with buildings.

The Institute was formally organized under the charter, April 8th, 1852, by the election of William B. Rogers, President; John A. Lowell, Jacob Bigelow, Marshall P. Wilder and John Chase, Vice-Presidents; Thomas H. Webb, Secretary; Charles H. Dalton, Treasurer; and through the liberality of some gentlemen interested in the undertaking, sufficient funds were immediately raised to begin operations.

The first meeting of the Society of Arts was held December 17, 1862. Since that time it has continued to hold two meetings a month during the successive sessions; the 146th meeting having been held May 23, 1872. At these meetings are presented communications on various subjects of applied science, with the exhibition of machines and apparatus illustrating important inventions in the mechanic arts.

By an Act of the General Court of Massachusetts, approved April 27, 1863, the Institute receives from the State "one-third part of the annual interest or income which may be received from the fund created under, and by virtue of, the 130th chapter of the Acts of the 37th Congress, at the second session thereof, approved July 2, 1862. . . Said Institute of Technology, in addition to the objects set forth in its Act of incorporation, shall provide for instruction in military tactics."

A report by Prof. Rogers, on the "Scope and Plan of the School of Industrial Science of the Massachusetts Institute of Technology," was submitted to the Government by the Committee on the School of Industrial Science, and adopted May 30, 1864. This elaborate and carefully considered scheme forms the basis of the instruction in all departments, with only such changes and additions in the details of the organization and equipment of the laboratories as time and experience could alone determine.

The School was opened with temporary accommodations in Mercantile Library Building, Summer Street, in Feb., 1865, with a class of 27 students. The successive catalogues show the following summaries: 1865–6, 72; 1866–7, 137; 1867–8, 167; 1868–9, 172; 1869–70, 206; 1870–71, 224; 1871–72, 264.

Besides the systematic day courses the Institute proposed as a part of its work "to provide evening instruction for persons of either sex, who, being unable to study during the day desire to avail themselves of systematic evening lessons or lectures." Before this part of the school was opened, the following letter was received: —

BOSTON, *Oct. 26, 1865.*

DEAR SIR: —

I propose to institute evening courses of instruction, to be opened gratuitously to the public, under such regulations as may be deemed advisable.

It has occurred to me that these courses might with advantage be delivered in the first instance under the supervision of the Massachusetts Institute of Technology, and by their professors; the programme of course to be acceptable to me.

I shall devote to this purpose $3,000 a year, to be divided among the teachers in proportion to the time devoted by each.

If such an arrangement would be acceptable to the Government, I shall be happy to confer with you upon the subject.

Yours respectfully,

(Signed) JOHN AMORY LOWELL,
Trustee Lowell Fund.

PROF. W. B. ROGERS,
President Mass. Inst. Tech.

The proposal of Mr. Lowell was gratefully accepted by the Government, and this important department of the school has since continued to be conducted with the approval of Mr. Lowell, and at the expense of the Lowell Fund.

Among the largest benefactors have been William J. Walker, Ralph Huntington, James Hayward, and William Powell Mason, deceased, and Nathaniel Thayer and John Amory Lowell. The following statement will show the amount of cash gifts which the Institute has thus far received.

In 1862, $3,000; 1863, $175,610; 1864, $3,000; 1865, $132,761; 1866, $30,700; 1867, $58,000; 1868, $76,800; 1869, $4,000; 1870, $24,415; 1871, $63,500; 1872, thus far $3,300. Total, $575,086.

Respectfully submitted,

J. D. RUNKLE.

SECRETARY'S REPORT

FOR THE YEAR MAY 1871—MAY 1872.

In conformity with article 16, section 4, of the By-Laws of the Corporation, I herewith present the Annual Report of the Transactions and condition of the Institute for the tenth year 1871-1872.

There have been held during the year fourteen meetings of the Society of Arts. The meetings have been generally well attended, and communications have been made on the following subjects:—

Nov. 9, 1871. President Runkle gave an account of the Institute expedition to Colorado and Utah during the summer, for the observation of the mines and mining processes. The party consisted of five professors and fifteen students. The expedition was in every way a success, both in giving the students valuable information and in securing for the Institute a large supply of ores from many localities.

Nov. 23. Prof. Richards gave an account of an expedition to Wyoming and the Laramie Plains, illustrated by a series of ores from the mining regions of Missouri, Colorado, and Utah.

Mr. Wm. E. Hoyt gave a description of several European bridges of modern construction, illustrated by black-board drawings and a set of models belonging to the Department of Civil Engineering in the Institute.

Prof. Pickering explained the methods of teaching physical manipulation in the Physical Laboratory as regards the engineering course, and with special reference to bridges.

Prof. Watson exhibited a modification of the endless screw, by which the wheel is made the driver and the screw the follower — a very convenient form for obtaining considerable speed.

Dr. Samuel Gregg exhibited and explained a model of a system of ventilation, devised by himself, by which he claimed that a free ventilation can be obtained in cold weather without loss of heat.

Prof. Watson exhibited and described, by means of the calcium light, Prof. Faber's Speaking Machine, then on exhibition in Boston.

Dec. 24, 1871. The Secretary gave an account, from personal observation, of the way in which the bed of the Mississippi river, in the upper part of its course, is gradually filling up from the sediment carried in from newly cultivated fields in Minnesota and Wisconsin — and of the diminished rainfall from the destruction of forests — seriously interfering with the navigation of the river.

Prof. Cross made a communication upon the methods employed in illustrating the lectures on physics, by means of photographs projected on a screen.

The Secretary announced the donation to the Institute, by Thomas Gaffield, Esq., of two large and handsomely framed oil paintings, representing the manufacture of plate and of cylinder glass.

Dec. 28. Mr. Langley described a spliced joint for uniting rails — an automatic road-maker — and a working model of a machine for coiling wire to be used for inside support for rubber hose and for making all kinds of wire springs.

Mr. J. A. H. Ellis gave a description of his process of utilising the heat in exhaust steam to produce power in a second and connected boiler, by the use of bisulphide of carbon, a volatile liquid boiling at 110° Fahr., and at the temperature of exhaust steam giving a pressure of 65 lbs. to the inch.

Jan. 11, 1872. Dr. Sternberg, U. S. A., exhibited in operation and explained an electro-magnetic apparatus of his invention, the object of which is the automatic regulation of temperature, wherever artificial heat is employed and an equable temperature desirable.

Mr. James Hamblet, Jr., made a communication on electric clocks and the telegraphic distribution of time.

Jan. 25. Dr. Van Zandt, of California, exhibited in operation and explained an apparatus devised by himself for lighting and extinguishing street gas lamps by electricity.

Prof. Watson made a communication, illustrated by diagrams, on the ther engine. He also exhibited some models and drawings, the work of the students in the department of Stereotomy.

Feb. 8. Mr. E. H. Hewins read a communication, illustrated by the calcium light, on European and American bridges compared.

Prof. Watson made some observations on the history of ancient bridges.

Prof. Pickering exhibited specimens of so-called "mineral wool," made by blowing high-pressure steam through melted slag; this is well adapted for steam packings and similar purposes, being incombustible and a non-conductor of heat. He also showed a plate of glass on which an engraving had been cut by the sand blast; and called attention to various methods of photographic engraving, some of which promise to revolutionize the art of book illustrations.

Mr. J. F. H. Markoe exhibited an improved achromatic stereoscope, from London, adjustable for all kinds of focal distances, and for each eye separately.

Feb. 22. Prof. Watson read a paper, illustrated by diagrams and models, on the history, construction, and recent improvements of turbine water wheels, accompanied by an account of some recent experiments to test their efficiency.

Prof. Richards made a communication, illustrated by the apparatus, on Gifford's Injector as a substitute for Bunsen's filter pump.

March 14. Mr. S. Dana Hayes read a paper, illustrated by experiments and specimens, on the "History and Manufacture of Petroleum Products."

March 28. Mr. McMurtrie explained by the aid of diagrams on the blackboard, the Blanchard boiler — in which the water space is divided by horizontal diaphragms into three nearly separate compartments, communicating only by small openings. He compared this boiler with other horizontal tubular boilers in Portland, Me., — stating that on a competitive trial a great advantage is claimed for it on the point of economy in fuel.

Prof. Richards explained the mining machinery recently put up in the laboratory of the Institute; after which the Society adjourned to witness its operation.

April 11. Mr. Langley exhibited and described a new fusible plug, and showed it in operation on a boiler.

Mr. J. A. Grosvenor explained a new injector, also exhibited it in operation.

Mr. Libby, of Medford, Mass., exhibited a model of a diagonal turbine water wheel of his invention.

April 25. Prof. Watson made a communication on Compound Marine Engines, illustrated by a model of the Engines of the Cunard Steamer "Hecla."

May 9. Mr. E. C. Merrill explained a process, invented by himself, of making artificial stone, illustrated by an extensive suite of specimens. His materials are oxide and chloride of zinc, and carbonate of baryta.

May 23. Mr. N. M. Lowe exhibited and explained a new instrument for recording by electricity the force and direction of the wind, devised by himself, with valuable suggestions from Mr. H. E. Cole.

Prof. Pickering then described the changes introduced in the department of Physics during the past year.

To show the practical nature of the work done this term by the students of the graduating class, a number of specimens of their handiwork were next described. They included a model

of a suspension bridge, having a span of about eight feet, a Howe truss, and a queen-post truss, and the flexure under different loads carefully measured by them. A new method of measuring the torsion or twisting of a beam under different loads was shown, using mirrors attached to each end, and placing opposite to them telescopes by which the reflection of a graduated scale was observed. A very slight motion of the beam and mirror moved the image of the scale several inches, so that extreme accuracy was thus attainable. The apparatus was also shown by which they had measured the cofficients of efflux or flow of water through apertures of various sizes, also the resistance or friction of water in pipes. These quantities form the basis of the science of hydraulics.

A chronograph for measuring very small intervals of time, as a hundredth or even thousandth of a second, was also shown. In this instrument, which was entirely the work of another student, Mr. Guild, the time is measured by the vibrations of a tuning fork drawing a line on smoked glass.

As work of quite a different kind, a collection of photographs were exhibited, taken by different students as a part of their regular studies, among them several views of objects seen under the microscope and greatly magnified. Although the platform and tables were covered with apparatus like the above, yet much remained that was not exhibited for want of room, showing that the amount of work done by the class was extremely large.

Among the advantages claimed for this kind of instruction the following may be mentioned: First, it cultivates the powers both of the mind and hand, and gives a thorough practical familiarity with methods of experimenting, commonly attained only by long and laborious trials on the part of the student after graduating, when called upon to perform these experiments in connection with his daily duties. Again, much of this work is of considerable scientific merit, and with proper means results might be obtained not only of great scientific value, but of

equal value to the mechanical arts, especially all matters relating to heat, steam and motors. The large amount of work is in a great measure due to the interest felt in the matter by the students themselves, who often come into the laboratory late in the afternoon, or during the dinner hour; and, since it becomes a pleasure, it is sure to be done well. Finally, many of the experiments once prepared by an older student can afterwards be used by the younger ones, and thus they are like so many assistants, improving the course for their successors at the same time that they are instructing themselves.

There have been elected during the year 13 members of the Society of Arts, of whom 12 have consummated their membership. One life member has joined during the year, Mr. Allen; no corresponding or honorary members have been elected.

Prof. Daniel Treadwell, the only Honorary Member, has died during the year; Mr. Jacob A. Allen, of Lynn, has also died, one of the victims of the Revere disaster. Deducting 2 who have died, 21 who have resigned, and 10 who have been dropped for non-payment of fees, there are now on the list 345 members, of whom 65 are life members, exempt from assessment.

About 280 students have attended the school of Industrial Science during the year. Of these, two are graduates pursuing an extended or post graduate course. In the first year were 91 students, in the 2d 39, in the 3d 33, in the 4th 17; and 90, not candidates for a degree, following various special or partial courses, principally chemistry, drawing, and architecture. Thirty-one professors and teachers are connected with the school, and the fees from the students have been about $37.000.

The apparatus for instruction has been largely increased during the year. Full details on the various departments of the school have been presented by the professors in charge.

The Lowell courses this year have been given on the following subjects:

A course of ten lectures on English Writers of the 18th and 19th Centuries, by Prof. Atkinson, on Wednesdays, at 7½ P. M. beginning November 15, 1871.

A course of eighteen lectures on Progressive Development of Life in Geological Ages, by Prof. Kneeland, on Tuesdays and Fridays, at 7½ P. M., beginning November 14.

A course of eighteen lessons in Elementary German, by Instructor Krauss, on Mondays and Thursdays, at 7½ P. M., beginning November 13.

A course of eighteen lessons in Elementary French, by Instructor Levy, on Mondays and Thursdays, at 7½ P. M., beginning January 22, 1872.

A course of twenty lectures in Elementary Chemistry, by Professors Richards and Nichols, on Tuesdays and Fridays, at 6½ P. M. beginning January 16.

A course of twenty-four Laboratory Exercises in Chemical Manipulations, by Professors Richards and Nichols, on Wednesdays and Saturdays, at 2½ P. M., beginning February 3.

A course of twenty-four Laboratory Exercises in Physics, by Prof. Pickering, on Wednesdays and Saturdays, at 2½ P. M., beginning February 3.

These courses were well attended, the greater number of persons availing themselves of the last two courses being engaged in teaching.

At a meeting of the Corporation, held June 13, the following votes were passed:—

Voted, That the Corporation will hereafter confer the degree of Bachelor of Science in the department of——, instead of graduate of the Massachusetts Institute of Technology, in the department of——, as heretofore.

Voted, To establish advanced courses of study and to confer the degree of Doctor of Science, subject to the following conditions:

1. *Advanced Students.* Bachelors of Science in any department of the Institute may enter upon these courses without examination; but bachelors of arts, science, or philosophy, of any

other institution, must give satisfactory evidence, by examination or otherwise, that they are fully qualified to enter upon any proposed course of study.

Any person may enter upon an advanced course of study, and become a candidate for the degree of Doctor of Science, who, by examination, shall be found qualified to take the degree of Bachelor of Science in any department of the Institute.

2. *Advanced Courses.* The course of study which any student may wish to pursue must be presented in writing and approved by the Faculty. His proficiency in this course will be tested by frequent examinations. All departments will be open to him, but there will be no examination required in voluntary studies.

The methods of instruction, whether by lectures, or projects, or field or laboratory work, will be adapted to each particular case.

3. *Term of Residence.* The minimum term of residence will be two years, but the degree will not be given until the student shall have fully completed his chosen course.

Occasional short absences from the Institute, spent in professional work by the advice of the Faculty, will be counted as residence.

4. *Examinations.* Periodical examinations will be held to inform the student as to his progress; and the results of all such examinations, as well as of the semi-annual and degree examinations, will be taken into account in conferring the degree.

He must present at least one printed thesis upon some subject embraced in his course.

5. The fees will be $150 a year, and the cost of materials consumed in laboratory work.

6. There are five advanced scholarships of $150 each which will be awarded by the Corporation on recommendation of the Faculty. Applications must be made to Samuel Kneeland, the Secretary of the Institute, in writing, on before the first of October next.

SAMUEL KNEELAND, Secretary.

Massachusetts Institute of Technology.

REPORT OF THE DEPARTMENT OF GEOLOGY AND MINING ENGINEERING.

To the President of the Institute:—

The changes recently made in the department of Geology, Mining and Metallurgy, and the very considerable additions made to the means of instruction in these studies, more especially the establishment of a Mining and Metallurgical Laboratory, are sufficient reasons for calling the attention of the Corporation to the present condition of this department.

The regular course extends over four years, and the range of studies pursued is indicated by the following scheme of instruction.

First and Second Years.

Mathematics. Algebra. Solid Geometry. Mensuration. Plane Trigonometry and Spherical Trigonometry. Analytic Geometry. Elements of the Calculus.
Surveying. Field-work. Plotting Surveys. Computing Areas. Plans.
Physical and Industrial Geography.
Physics. Mechanics of solids, liquids and gases. Sound. Light. Heat. Magnetism. Electricity.
Chemistry. Qualitative Analysis. Chemistry, Organic and Inorganic.
French.
German.
English.
Descriptive Geometry.

Mechanical and Free-Hand Drawing.
Descriptive Astronomy.
Physiology and Hygiene.

Third Year.

Civil Engineering. Survey and Construction of Roads and Railways. Measurement of Earthwork and Masonry. Field Practice.
Mathematics. Differential and Integral Calculus. Analytic Mechanics.
Applied Mechanics. Stress. Stability. Strength and Stiffness.
Geology. General descriptive and theoretical Geology.
Zoology and Palæontology.
Mining. Ore-deposits. Prospecting. Boring. Sinking Shafts, etc. Methods of Mining.
Mineralogy. Descriptive and Determinative. Crystallography. Use of the Blowpipe.
Chemistry. Lectures and Laboratory Practice in Quantitative Analysis.
Assaying. Wet and dry ways.
Metallurgy. Metallurgical processes. Constructions and Implements.
Physics. Laboratory Practice.
English and Constitutional History.
French or Spanish.
German.
Drawing.

Fourth Year.

Mining. Ventilation. Winding-machinery. Underground-transport. Pumps. Dressing and Concentration of ores. Practice in Mining Laboratory in Ore-dressing.
Economic Geology. Detailed description of American ore-deposits and mines.
Strength of Materials and Hydraulics.
Machinery and Motors. Hand-machinery. Water-wheels. Boilers. Steam-engines.
Chemistry. Lectures, and Laboratory Practice. Synthetic Experiments. Quantitative Analysis.
Geology. American Geology; Lithological, Stratigraphical, Palæontological.
Chemical Geology. Origin of rocks, vein-stones, ore-deposits, coal, petroleum, salt, etc.
Metallurgy.
Practical Lithology and Building materials.
Physics.

Drawing. Geological Maps and Sections. Plans of Mines. Mining Machinery and Implements.
English Literature.
Political Economy.
French or Italian.
German.

The four years' course is so arranged as to secure to the student a liberal mental development and general culture, as well as the more strictly technical education which is his chief object.

The studies of the first and second years are somewhat general in character, but are regarded as a necessary foundation for the more special studies of the two succeeding years.

The special professional studies peculiar to this department commence with the third year.

Instruction is given by lectures and recitations, and by practical exercises in the field, the laboratories and the drawing-rooms. In most of the subjects problems are given the students, to be worked out outside of the lecture-room. A high value is set upon the educational effect of these practical exercises.

The space devoted to laboratories, and the prominence given to laboratory work, in Physics, Chemistry, Assaying, Blowpipe-analysis, Metallurgy and Ore-dressing is a marked feature in the scheme of instruction of the Institute. It is believed that this school offers unusual facilities in this regard.

The Chemical Laboratories cover 4,000 square feet.

The Mining, Metallurgical, and Assay Laboratories cover 2,000 square feet.

The Blowpipe Laboratory covers 550 square feet.

The Physical Laboratories cover 3,500 square feet.

The Drawing Rooms cover 8,556 square feet.

A course of thirty lectures on Physical Geology and Geography is given to the students of the second year by Professor Niles.

The study of the surface of the earth, of its external fea-

tures, their origin and modifications, is essentially the subject of this course. A proper knowledge of the surface includes necessarily a corresponding acquaintance with the arrangement of rock-masses, in so far as they have determined the character of the surface-features, and especially the geological agencies which are constantly producing the changes of the surface.

The aim of the instruction, in the course of Prof. Niles is, therefore, to present clearly the most important relations between surface features and underlying geological formations, and to show the action of the great dynamical forces; or in other words to teach Physical Geography and Physical Geology in their natural relations.

The knowledge of these relations becomes of great practical value in determining the extent or even probable occurrence of certain ore-bearing rocks, and of coal-beds in certain districts, since, where the rocks are completely covered by soil, the topographical features may be the only guide in "prospecting."

Exercises, Third and Fourth Years.

Descriptive and Theoretical Geology	30 lectures	Prof. Hunt.
American Geology	30 lectures	" "
Practical Lithology and Building Stones	15 lectures	" "
Chemical Geology	15 lectures	" "
Mining	70 lectures	Prof. Rockwell.
Economic Geology	20 lectures	" "
Palæontology	50 lectures	Prof. Hyatt.
Metallurgy	40 lectures	Prof. Ordway.
Industrial Chemistry	40 lectures	" "
Quantitative Analysis	40 lectures	Prof. Crafts.
Chemical Laboratory Practice.	10 to 15 hours a week	" "
Assaying, dry way	10 ex. (2½ hrs. each)	Prof. Richards.
Blowpipe and Determinate Mineralogy	45 ex. (1 to 2 hrs. each)	" "
Descriptive Mineralogy	15 lectures	" "
Mining and Metallurgical Laboratory Practice	10 hours a week	
Physical Laboratory Practice	3 hours a week, 1 year	Prof. Pickering.

Calculus	60 lessons	Pres. Runkle.
Mechanics	60 lessons	" "
Civil Engineering	40 lessons	Prof. Henck.
Strength of Materials and Hydraulics.	40 lessons	Prof. Watson.
Machinery and Motors	25 lessons	" "
Natural History	25 lectures	Prof. Kneeland.
French	2 hours a week	
German	2 hours a week	
English	2 hours a week	
Drawing	3 to 6 hours u week	

GEOLOGY, LITHOLOGY, ETC.

The instruction in Geology and certain related subjects is given by Prof. Sterry Hunt, in four courses, delivered yearly to students of the 3d and 4th years.

I. *3d Year.* The *first* is a yearly course of thirty lectures on *Descriptive and Theoretical Geology.* This embraces the classification of the Sciences; Scope of Geological Studies; Nature of Rocks, or Lithology; Stratigraphy; Succession of Formations; Zoological History; Geological Dynamics; Chemical and Physical Forces; Aqueous and Igneous Agencies; Currents; Sedimentation; Elevation and Subsidence; Geographical Distribution of Formations; Nature and Origin of Mountains; Volcanic Action.

II. *4th Year.* The *second* is a yearly course of thirty lectures on *American Geology*, comprising Introduction; Geological History; Geology of North America, considered (1) Lithologically; (2) Stratigraphically; (3) Palæontologically; Comparative Geognosy.

III. The *third* is a yearly course of fifteen lectures on *Practical Lithology*, comprising the mineralogical composition of Rocks; Building-stones, their cohesion, porosity, etc.; Granites, Marbles, Limestones, Sandstones, Slates; Limes, Cements, and Mortars; Ornamental Stones and Gems.

IV. The *fourth* is a yearly course of fifteen lectures on *Chemical Geology*, or the Chemical History of the Globe; comprising the Origin of Rocks, both stratified and unstrati-

fied; the History of Vein-stones and Ore-deposits; the Formation of Coal and Petroleum; the Chemistry of Salt-deposits and of Mineral Waters; the Seat and Origin of Volcanic and Earthquake phenomena.

MINING AND ECONOMIC GEOLOGY.

The instruction in Mining and in Economic Geology is given by Prof. Rockwell, in two yearly courses, delivered to students of the 3d and 4th years.

I. The *first* is a yearly course of 70 lectures on *Mining*. The student is made acquainted with the general character of the various deposits of the useful minerals, and with the theory and practice of mining-operations, such as the methods of search or "prospecting," — boring for oil, coal or water,—the sinking of shafts, with the timbering, walling or tubing of the same, the driving of levels; the different methods of working lodes, coal-beds, etc., the underground-transportation of the mineral, hoisting, pumping, ventilation and lighting, together with the machinery and other appliances connected with these and other operations; in short, the great variety of operations comprised under the general term, Exploitation. Ore-dressing, or the mechanical separation of ores from their gangues, is discussed somewhat at length, and the machines described by means of which this concentration is most economically effected. The practical course of ore-dressing and smelting in the Mining and Metallurgical Laboratory, affords the student opportunities for acquiring a familiar knowledge of the treatment of ores, such as can be got, under ordinary circumstances, only at the best mines.

II. The *second* is a yearly course of twenty lectures on *Economic Geology*, mainly devoted to a detailed description of the coal and ore-deposits of North America, especially such as are most extensively worked.

The student who is a candidate for the degree of the Institute, is expected to spend a portion of his vacations in some one

of the principal mining-districts in the study of the local peculiarities of the ore-deposits, and the details of actual working, and to submit a full report upon the same, with drawings. Those who intend to become metallurgists, may take smelting-works instead. Through the kindness of several proprietors certain mines in different regions have been made accessible to students, for the purpose of systematic study.

METALLURGY AND INDUSTRIAL CHEMISTRY.

The instruction in Metallurgy and in Industrial Chemistry is given by Prof. Ordway, in two courses of two years each, delivered to students of the 3d and 4th years.

I. The *first* is a two years' course of forty lectures on *Metallurgy*. The subjects discussed are fuels, fluxes, slags, furnace construction, and the roasting, smelting and refining of the various metals.

II. The *second* is a two years' course of forty lectures on *Industrial Chemistry*. The manufacture of acids, alkalies, salts, pottery, glass and organic products, and the arts of dyeing and printing are the principal subjects treated of.

In connection with these lectures, excursions are made to Manufactories and Metallurgical Works, and practical exercises are given in the laboratories. The students are required to make drawings and designs of apparatus used or to be used in large operations.

MINING AND METALLURGICAL LABORATORY.

The purpose of this laboratory is to furnish the means of studying experimentally the various processes of ore-dressing and smelting. Ores of all kinds are here subjected to precisely the same treatment, and by the same machinery and other appliances that are in use at the best Mines and Metallurgical Works of this and other countries.

The laboratory has already in successful operation the most approved Ore-dressing and Mill-machinery for gold and silver ores now in use in California and Nevada; consisting of a *five-stamp-battery*, an *amalgamating-pan*, a *separator* and a *concentrator*, complete in every respect, and capable of treating half a ton of ore a day. These were obtained the past summer in San Francisco. There will be added during the present year an ore-crusher, a hydraulic jigger, a Rittinger shaking-table, and all other appliances necessary for the treatment of every kind of ore. The machinery is driven by a steam-engine of upwards of 15 horse-power.

For Metallurgical treatment the laboratory contains at present a reverberatory roasting-furnace, crucible and assay-furnaces, and a blacksmith's forge; and there are now being erected reverberatory and blast smelting-furnaces capable of working 400 pounds of ore per day, and a cupelling-furnace sufficient for working 50 pounds of lead at once. To these will be added retort and other smaller furnaces for various uses. All of these will be ready for use by October of the present year.

The experimental work of this laboratory is carried on by the students, under the immediate supervision of Prof. Richards. A sufficiently large quantity of ore is assigned to each student, who first samples it, and determines its character and value by analysis and assays, and makes such other preliminary examinations as serve to indicate in a general way the proper method of treatment. He then treats the given quantity, makes a careful examination of the products at each step of the process, ascertains the amount of power, water, chemicals, fuel and labor expended. In this way the same ore is subjected to several methods of treatment, and by a comparison of the results obtained, the student learns the relative effectiveness and economy of different methods, as applied to the same ore. It is believed that the experiments conducted in this way, and upon such a scale, will prove of direct practical value, not only to the student, but to the Mining interest at large, by showing how existing methods of treatment may be advantageously modified meet the requirements of new complex ores.

The Institute has now on hand about eleven tons of gold and silver ores, representing over seventy different mines in Colorado and Utah, which were collected by the Institute-party of professors and students during their recent trip to these territories. These ores will be worked, and reports of the results sent to those who so generously contributed them; and it is hoped that by such coöperation the laboratory will continue to receive the necessary amount and variety of ores.

The following experiments upon gold ores have been begun; but all the products have not yet been fully tested, on account of the approach of the annual examinations: —

1. The —— Lode, Nevada City, Colorado, 324 lbs.
2. The —— Lode, Nevada City, Colorado, 110 lbs.
3. The —— Lode, Central City, Colorado, 255 lbs.
4. The —— Lode, North Carolina, 103 lbs.
5. The —— Lode, Central City, Colorado, 250 lbs.

PALÆONTOLOGY.

The instruction in Palæontology is given in a yearly course of 50 lectures by Prof. Hyatt, one-half of which are delivered to the 3d year and one-half to the 4th year students.

Palæontology, or the history of ancient animal life, and Stratigraphical Palæontology, or the study of the distinctive and characteristic fossils of the different formations, are taught as a necessary foundation for the further study of Geology. The aim of the course is to give the student a practical acquaintance with the structure of the characteristic families, and orders of living and extinct animals, and by a judicious selection of examples to familiarize him to some extent with the genera which characterize various formations.

The handling and the drawing of specimens by the students is an essential feature of the method of instruction. The lectures of the instructor are devoted largely to explanatory demonstrations of the specimens which the students are at the same time drawing. The success attending this mode of teaching palæontology has shown its value.

MINERALOGY AND BLOWPIPE PRACTICE.

The instruction in Mineralogy and the use of the Blowpipe is given by Prof. Richards, in two courses to students of the 3d year.

I. The first is a course of 45 exercises (of one to two hours each), in which the student is taught Determinative Mineralogy by the study of crystalline forms, and the physical properties of minerals. He is instructed in the use of the blowpipe for the qualitative determination of minerals, and in the quantitative assay of silver and copper ores.

II. The second is a course of fifteen lectures on Descriptive Mineralogy, accompanied by critical examinations, and the handling of specimens on the part of the student.

ASSAYING.

The instruction in assaying is given by Prof. Richards in a course of ten exercises (of two to three hours each), in which the student learns to perform the ordinary dry assays of gold, silver, lead and other ores. Instruction in wet assaying is given by Prof. Crafts.

CHEMICAL COURSE FOR MINING ENGINEERS.

The chemical instruction of the mining-students extends through the four years. The course in General Chemistry occupies the first year; and during this time the students work two hours each week in the chemical laboratory. Each student performs for himself a great variety of experiments designed to illustrate the properties of the various chemical elements and of their more important compounds: he also prepares a number of such simple and compound substances as are of use in the arts or serve to illustrate the laws of chemical change. The knowledge thus acquired by the practical work of the laboratory is

supplemented and enforced by lectures, recitations and frequent examinations.

During the second year, more particular attention is given to the theory of Chemistry, and to Qualitative Analysis. The latter branch of the subject is taught by laboratory-exercises, each student working four hours a week. As during the first year's course, these laboratory exercises are accompanied by recitations and examinations.

During the third year the mining-students take a systematic course of quantitative analyses, occupying six hours per week in the laboratory, and attend a weekly lecture, or exercise in which methods of analysis are discussed, and the results of investigations too recent to be found in text-books are presented to them. Mining-students may take in addition, as a voluntary exercise, a course of special analytical methods, reciting from German text-books.

In the fourth year the students are engaged in laboratory-work during the hours between 9 A.M. and 5 P.M., which are not devoted to recitations and problems in drawing, metallurgy, etc., which more nearly concern their professional studies. They all get about three hours daily for chemical work; and many are able to spend more time in the laboratory without neglect of their other studies. They accomplish a tolerably thorough analytical course, comprising the analyses of salts, the more common minerals, and particularly of ores and metallurgical products, and extending as far as the more difficult analyses, such as the determination of all the constituents of cast iron or steel; so that a student in his professional work as a mining-engineer may be independent of the assistance of a chemist, and competent to deal with all ordinary investigations.

Some students, who show a special aptitude for chemistry, are encouraged to take up special investigations connected with metallurgy; and all accomplish work which may be considered a sufficient preparation for their professional career.

PHYSICS.

The instruction in Physics, extending through the first three years of the course, is given by Prof. Pickering. During the first two years the whole subject is thoroughly discussed mathematically and experimentally in lectures illustrated from the extensive collection of physical apparatus of the Institute.

In the third year the students enter the Physical Laboratory, and learn to use the different instruments and to perform a variety of experiments. Special attention is paid to the testing of physical laws by comparing the observed and computed results.

The students further carry on systematic investigations of particular subjects, during the fourth year, and pursue such courses of experimentation as have a direct bearing on their professional studies.

COLLECTIONS.

The geological collection of the late Prof. Henry D. Rogers of the University of Glasgow, presented to the Institute by Mrs. Rogers, is made up chiefly of fossils and rock-specimens from American localities, and in certain branches is peculiarly valuable for instruction. The collection of ores and vein-stones is already large and varied, and is constantly receiving additions from the various mining regions.

A typical set of models of mining-machinery, chiefly from Freiberg, Saxony, is used in the course of instruction. They are designed mainly to illustrate the principles of the various processes of mining and ore-dressing, but combine also the latest improvements in machines. They show in detail the methods of working underground by underhand and overhand stoping, the timbering and walling of shafts and levels, the arrangements of pumps, man-engines, ladder-ways, hoisting-ways, the sinking of shafts, etc. The machines for ventilation as well as those for ore-dressing are working models. The latter illustrate all the stages of the concentration of ores.

The collections and library of the Boston Society of Natural History are, by an agreement between the Society and the Institute, freely open to the students. These collections rank among the first in the country for extent and value, and in many departments are unsurpassed; the library is rich in works on Geology and Natural Science and embraces the leading American and European journals and periodicals on those subjects.

The instruction in certain subjects is given by the Professors of the Institute in the lecture-room of the Natural History Society, whose building is upon the same square with the Institute of Technology.

The private collections of some of the professors, especially that of Prof. Hunt (which is very complete in lithology and mineralogy), are available for purposes of instruction.

The Boston Public Library. The professors and students of the Institute are also allowed the full use of this extensive and valuable library.

REPORT UPON THE INSTRUCTION IN QUANTITATIVE ANALYSIS IN 1871-1872.

The opening of a new laboratory room has increased by about three-fifths the space devoted to the work of the third and fourth years' classes in Quantitative Analysis, so that the desk-room is amply sufficient for the ordinary work of classes of the present size.

It has, however, been found impossible to secure the small rooms, which should adjoin the main working rooms, and which should contain the more delicate pieces of apparatus, such as the balances, microscopes, spectroscopes and apparatus for gas-analysis. In default of these, a glazed partition has been thrown across a part of one of the laboratories, and in this way, without sacrificing the light of a window, a small room has been provided for the balances and the chemical library, which answers its purpose very well; but unfortunately it is not far enough removed from the laboratory to secure the balances from danger of injury from acid fumes, which occasionally escape into the air of that room as the result of an accident. The weighing room is also too small for laboratories provided like ours with places for forty-six students. The cases in which operations with acids are carried on, are connected with flues having an excellent draught, and thanks to them it has been found possible, with careful manipulation on the part of the students, to keep the air of the laboratories as pure as it usually is in such rooms; but this task is rendered irksome by a deficiency in proper ventilating flues opening directly into the rooms,

and by the fact that the rooms, having a low ceiling, offer a restricted bulk of air to deal with. These are defects which cannot apparently be remedied in the existing building.

Several new appliances for facilitating the laboratory work have been introduced during the past year. These include, besides improved forms of apparatus, some of those labor-saving contrivances, which may find their place in a laboratory as well as in a work-shop. Under Professor Ordway's directions several wrought iron steam boxes, capable of resisting a great pressure, have been purchased and set up. They are connected with the boilers used for heating the building, and when the steam is passing through them they serve as iron tables, which can be maintained at a constant temperature, and on which solutions to be evaporated can be left without danger of being over-heated.

One of the most remarkable improvements in analytical chemistry has been the introduction by Professor Bunsen, of Heidelberg, of an ingenious mechanical attachment to the ordinary filters, allowing them to be connected with a very simple air pump, worked by water and greatly accelerating filtration. A few such pumps had already been constructed in the school, after the discovery by Professor Richards of some important improvements in their form. This year one has been set up at each desk in the new laboratory, while means are provided to the student for making for himself the apparatus attached to the filters. These appliances have proved so easy to manage, so inexpensive, and of such value in shortening the time required for analysis, and consequently allowing the student to take a more extended course, that it is proposed to provide each desk in the old laboratory with them next year.

A new method of making copper assays, which has lately been tested with great thoroughness in Germany, has been successfully tried in the laboratory, and even beginners have obtained very exact results with it. The process depends upon the use of a galvanic battery, and a number of these of Meidinger's pattern, which remains in constant action many weeks,

have been set up in different parts of the laboratories. It was deemed that such processes would be of little use to the student in his after career, unless he could easily procure the necessary apparatus, and it was therefore considered an essential part of his instruction to suggest to him by examples, ways of supplying his needs with the commonest materials.

The batteries in question were made in the laboratory from pieces of lead pipe and broken bottles, and the perishable part, which is the zinc element, was cut from the thick plates of zinc, which have been introduced of late years for sheathing vessels. With a few hints in such directions a student may often supply himself at a small cost with apparatus that is not attainable ready made in this country; and in this connection may be mentioned a new apparatus for weighing hygroscopic bodies, made entirely by the students, of which an account will shortly be published; also the preparation by some of the students of their own measuring tubes for gas analysis, which are graduated by means of Bunsen's simple instrument, and the graduations are afterwards etched upon the glass.

In the absence of a proper room for gas-analysis, through Professor Pickering's kindness, a portion of the physical laboratory has been set apart for this purpose, a sufficient quantity of mercury has been purchased and instruction in this important part of a chemical course will be given next year.

As important additions to the laboratory apparatus may be mentioned a Hofmann's combustion furnace, and a new balance by Becker. A spectroscope by Steinheil of Munich, a saccharometer by Soliel of Paris, with quartz compensating prisms, and a very large and delicate balance by Lingke of Freiberg, have been placed at the service of those students who require them for any special purpose.

The progress of the students in their analytical work has been satisfactory, and a considerable number of them have voluntarily spent more than their required time in the laboratory.

The students who take the course in Quantitative Analysis are of two classes, those who take it as a part of their course in Mining Engineering, and those who make it their principal study with the intention of becoming chemists. It was felt that the distinction between the studies required in each course was not sufficiently marked, and that the chemical students had time to take up more of the theory and practice of chemistry, than the pressure of the other studies of the mining students would allow them to attend to during the last term.

By way of experiment two new classes were established; one a voluntary class of the third year's students, reciting from a small German text book upon some special subjects in analytical chemistry; the other comprised all the chemical students of the fourth year's class, as well as two volunteers, who were graduates of the school. The subject was organic chemistry, and it was looked upon from two points of view. In the first place an endeavor was made by using very advanced text books, and by giving citations from the chemical journals of the most important of the discoveries, more recent than the text books, to show the student where to look for the complete description of the facts, which subsequent work might require him to study, and at the same time to impress upon his memory the more important points, presenting them in relief against the minor ones. In the second place considerable attention was paid to the somewhat intricate theories of organic chemistry, in the belief that it is the best ground upon which to encounter and master the theories of chemistry in general.

The choice of text books was left free and the larger number in the class selected Kekulé, a work in German, and the most complete yet published on the subject. It was with some apprehension that this formidable text-book in a foreign language was attacked, but the experience of the term seems to approve the choice.

The lessons covered about twelve hundred pages octavo and of course the whole text was not even read in preparation for a recitation, but it was not difficult to select the more important statements; familiarity was gained with the arrangement of the

best guide to a complete knowledge of the subject, and a favorable position attained for beginning its thorough study as a specialist when separated from the assistance of a teacher. Some stress may be laid upon the value of the acquirement of the technical words in German during a course of study of this kind.

It is very possible that the class of this year were unusually well fitted to take up this subject, several of them reading German with ease, and certainly it would be premature to found a decided opinion about the best course for the future upon so short an experience; it has been determined, however, to require next year, for the chemical students of the third year's class, an additional course in a special branch of analytical chemistry from a small German text book (no good English one on the subject is procurable), besides the regular course of lectures on analytical chemistry, which are taken by the chemical and mining students alike; and in the fourth year's course, the chemical students willhave two recitations a week on or ganic chemistry, accompanied by lectures, and the choice of text-book will be left free. A written description has been given to the class of several text-books, and no advice as to a choice is given, even when asked. Success with one or the other depends so much upon the character of the person using the book, that it is thought desirable to leave the responsibility with each individual.

In conclusion, the fruits of the year's work which we can offer to the public, are two short investigations ready for publication, one made by a student of the graduating class who has shown an unusual aptitude for chemical work, another by one of the professors.

It is to be hoped that in the future a larger number of the students may be able to go over untrodden ground before finishing their course, and also that the laboratory may offer sufficient inducements to attract more experienced workers to make investigations there.

J. M. CRAFTS,
Professor of Analytical and Organic Chemistry.

June 3, 1872.

REPORT OF THE DEPARTMENT OF ARCHITECTURE.

President Runkle, Dear Sir:—

At the close of the fourth year in which this Department has been in active operation I beg to present the following account of its present condition, of what it has thus far accomplished, and of what had previously been done by way of preparation for this work.

This preparation had consisted chiefly in such examination as I had been able to give to foreign schools of architecture, with some personal consultation with architects both in this country and abroad, and in the collection of casts, photographs and drawings, and other materials, which the generosity of some friends of the school had given the means of purchasing. Some unusually favorable circumstances rendered these collections much more extensive and valuable than was reasonably to be expected, especially in respect to mediæval sculpture and carvings and architectural drawings. A large and almost unique collection of casts from Lincoln and Southwell fortunately fell into my hands, which, I was afterwards able to supplement by considerable additions from French Gothic work of the same period. At the moment of returning home I was also enabled, by the generosity of Mr. Ernst Benzon, of London, formerly a resident of Boston, to purchase an unusually good collection of school drawings, made by students in architecture at the Ecole des Beaux Arts, in Paris, and at the French Academy in Rome.

These collections were largely augmented by the kindness of many gentlemen, mostly architects, who, both in England and on the Continent, evinced a lively interest in our undertaking, and contributed not only photographs of their works, but tracings and lithographic copies of working drawings, with specimens of specifications, estimates, bills of quantities and various forms of business papers. Our thanks are specially due to Mr. Waterhouse, Mr. Withers, Mr. Keeling, Mr. Norton, Mr. Nash, Mr. Rickman, Mr. Edis, and the late Mr. Papworth in London, and Mr. Bryce in Edinburgh, and to M. Viollet le Duc, M. Charles Garnier and M. Lesoufacher in Paris, for their generous contributions. M. César Daly also presented to the department his valuable work illustrating the domestic architecture of the Second Empire, and the French Minister of Public Instruction, M. Duruy, acting through our Minister, Gen. Dix, put at our disposition a number of illustrated works relating to the architectural history of France, among which were the magnificent monograph of the Cathedral of Chartres and the two volumes entitled the " Statistique Monumentale de Paris." The Secretary of the Institute of Scottish Architects in Edinburgh also gave us a nearly complete series of the publications of that Society, the Architectural Publication Society of London added their miscellaneous publications, and the Royal Institute of British Architects not only presented us with a complete set of their valuable Proceedings, but were good enough to put us upon their books, so that we have continued regularly to receive the papers they have published. Altogether, besides these books and papers, the collections comprised, at the moment of opening the school, about 2,000 photographs, 500 prints, 400 plaster casts, 200 crayon drawings, 40 water-colors, mostly of architectural subjects, and 30 manuscript architectural drawings, large and small, besides 100 sheets of working drawings, mostly tracings, and some specimens of tiles, pottery and stained glass.

These various objects were classified and arranged in the rooms of the Architectural Museum during the spring and summer of 1868, and wall-catalogues giving the names of a

chief part of the plaster casts were printed for the convenience of visitors, of whom several hundred visited the Museum during the next year. On the opening of the Department at the beginning of the school year in October, sixteen pupils presented themselves, four of whom were special students in architecture within the school, spending their whole time over their school-work. The others were students or draughtsmen in offices, coming to the school only to attend lectures.

During this year the lectures were mostly historical and critical, as a part of the Course of Design, the Course of Construction not being undertaken. A course of lectures upon Perspective, however, was given in the course of the winter, which was attended by the whole of the Third Year's class. The work of the year, after some preliminary exercises in the use of india-ink and color, consisted of a series of problems in design, of gradually increasing difficulty, originated and worked out by the students under my advice and supervision; such as, among others, a Balcony, a Bridge, a Triumphal Arch, a Swimming Bath, a Mausoleum, a Chapel, and some problems of ornament, such as a Honeysuckle frieze, a four-leaved Corinthian capital, etc., etc.

The second year, beginning in October, 1869, I was fortunate enough to secure the services, as my assistant, of Mr. Francis W. Chandler, now Assistant Supervising Architect of the Treasury Department at Washington. Mr. Chandler had formerly been a student and draughtsman in my office, and had then just returned from the completion of his studies in Paris. He continued in the school until the first of April, spending his whole time in the drawing-room, giving the class just at the moment each might need it the benefit of his advice and assistance. The marked improvement made by the class under this arrangement convinced me, of what indeed hardly to my mind needed this proof, that the only way to secure rapid progress in this work is to have personal instruction from a highly accomplished teacher constantly at hand to save the students from the loss of time and trouble, which, in the beginnings of so

difficult and complicated a study must otherwise be very great. During the last part of the year the class were strong enough to get along without more constant supervision than I could myself give them. I, however, engaged the services of Mr. Langerfeldt to give them lessons in water-color drawing, and of Mr. Virgil Williams, who for several months gave them lessons in crayon drawing several times a week.

During this year there were twenty-two students attached to the Department, of whom twelve were students in offices, and only attended lectures. The other ten spent their whole time at the school as special students in Architecture, many of them taking in addition to their professional work some of the mathematical or other studies open to them in the school.

My own work comprised, besides the instruction given to the class in Design, of the same general character as the year before, a course of lectures in Construction, in which the ordinary detail of office work was gone over in connection with the specifications and working drawings. The work of the class, in like manner, comprised, besides the series of problems in design, the working drawings of a small frame house, with details and specifications, according to designs of their own. The problems in design embraced, among other things, a Campanile, employing the Doric, Ionic and Corinthian orders; a Hospital and Alms House for 40 pensioners, with Chapel, Refectory, Hospital, etc., all with open roofs; a set of church furniture, font, pulpit, etc., etc.; a half-timbered house; a school and library building, with passage to a church beneath; a summer-house between two bridges; and a number of minor subjects. A considerable number of the drawings embraced in these series were drawn in perspective. Much of the work was in the Gothic style.

The Boston Society of Architects, "wishing to do its part in the work of architectural education," established this year two annual prizes, consisting of books, of the value of fifty dollars each, to be given to the students who should exhibit at the end of the year the best year's work. A committee consisting of Mr. Cabot, Mr. Cummings and Mr. Van Brunt, awarded the

prize for the best work in the class of Design to Joseph A. Pond, of Allston, and a committee consisting of Mr. Hartwell, Mr. Preston and Mr. Brigham awarked the prize for the best work in the class of Construction to William M. Woollett of Albany, N. Y.

The third year, from October, 1870, to June, 1871, the class numbered fourteen special students, many of whom were the same as the year before, with only two or three from the offices. Indeed, experience had shown that it was almost impossible for young men actively employed as draughtsmen to command time for any other stated avocation, by day. The attendance of this class of students had in the previous years been very irregular, ceasing almost altogether towards the end of the year.

The work resembled very closely that of the previous year, except that for accidental reasons, although the lectures in construction were carried on, the work done by the class under this head was but slight. The prize in construction was accordingly not awarded. That in design was given to Frank Spinning, of Dayton, Ohio. Mr. Langerfeldt and Mr. Williams continued their lessons in water-colors and crayon-drawing, and towards the end of the year the class had a course of a dozen lessons in modelling under the care of Mr. Alexander Johnston.

Mr. Chandler's engagements were such that, to my great regret and that of the class, he was obliged to relinquish part of his work at the school in January, and on the 1st of March gave it up altogether. It proved impracticable to supply his place either for the remainder of the year or for the year to come, very few young men in this country having the sort of training that fits them for school-work, and those few being in great demand for other work. In this case there seemed to be only one course left, and as soon as Paris was open to the mails I wrote to my correspondents both there and in London, begging them to employ their good offices to find among the young men about to leave the École des Beaux Arts some one competent and suitable for our vacant post. It ws not until the month of December, however, that any definite result wa

reached, and it was January before I had the pleasure of welcoming my new assistant, Mr. Eugene Létang, and the satisfaction of sharing with him a labor whch I had borne almost without assistance since the preceding March.

This somewhat adventurous step, which from the circumstances of the case I was obliged to take almost upon my sole responsibility, has met with a success even greater than I had hoped. In professional attainments, I knew that of course a student of the *Première Classe*, a pupil of so eminent an architect and successful an instructor as Mr. Vaudremer, could not but be a thoroughly accomplished architect, and one thoroughly versed in the best methods of the best system of architectural discipline. Still, it is not without anxiety that one invites a foreigner to take part in our own undertakings, and in the present case there was cause to fear that the obstacle of language might prove an insuperable one. The event has proved, however, that these fears were unfounded. The awkwardnesses of the position have been met with tact and good sense, and as the young men have for the most part some knowledge of French, and are glad to practice what they know, what promised to be a source of embarrassment has been, in fact, a positive advantage. But of late English has again begun to prevail in the drawing-rooms.

The year's work has been of substantially the same character as before, except that during the last half of the year a considerable number of small problems, each occupying only a couple of days, or at most a week, have been introduced. The subjects of these have been, for instance, a Porch, a Carriage-Porch, a Portico in a Garden, a Peristyle, a Mantel-piece, etc., etc. The crayon or charcoal drawing has also, in Mr. Létang's hands, assumed a more prominent position, and the class have made good progress in it. I have also required the class every morning to bring in in their sketch books a pencil-sketch of some building, a plan, or an architectural detail, an exercise in every way salutary. A considerable part of the class have also done a fair amount of work in Descriptive Geometry, and in

shades, shadows and perspective, partly under my own instruction, and partly in connection with other departments of the school. The study of Detail Drawings has also been pursued with very satisfactory results, though to but a limited extent, in connection with lectures upon Carpentry and Joinery. It is impossible to go very thoroughly into these subjects without an entire interruption, for the time, of everything else. But in view of the fact that a chief part of the class were looking to spend a portion, at least, of their four months' vacation in architect's offices, it seemed best to do what could be done in preparation for that work.

The different topics embraced in the Lectures have been chosen so as to illustrate as far as possible the work the class might have in hand. These have been on Construction, on History and Criticism, on Shades, Shadows and Perspective, and the Perspective of Shadows, on the Composition of Mouldings, of Details and of masses; on the Orders, on the Topography of Rome, on the Tuileries and the Louvre, making about seventy lectures in all, delivered two or three times a week, and occupying an hour and a half or two hours each in the delivery. It has been necessary to give a good deal of information, *viva voce*, that might better have been obtained from text-books, if proper text-books were to be had. Indeed, a chief part of my own labor has consisted in collecting and putting into shape the common-places of architectural information, things which every architect knows, but which are not as yet accessible to students.

These various works occupied the first six months of the year, and sufficed for preliminary study. On the 1st of April a more important subject was taken in hand, which has occupied the rest of the year; the sketches and finished drawings for a Casino or Pleasure House, situated in a formal garden and surrounded with statues and fountains. This sort of subject, though remote from daily use and experience, is for that very reason best suited to this stage of advancement, as it necessitates the close study of the best masters, stimulates the fancy

and imagination, and does not involve the numberless considerations of practical detail, which it would not do to slight, and yet which the class are not yet prepared to entertain. A more practical problem would require for its solution a more extended experience than such a class can possibly have had. Work of this kind, on the other hand, while it taxes their powers to the utmost, both in the design and in the execution of the drawings, does not demand for its satisfactory performance any greater resources, either of knowledge or skill, than they have at command.

The result has amply justified this view, which is, indeed, supported by our own previous experience and by the practice of the best schools abroad. The progress of the class during these eight months, in the essentials of professional culture, has been very satisfactory. It is only by such incessant practice of original design, under proper guidance and criticism, that the creative and imaginative faculty can be exercised and developed. Moreover, it is through the varied manipulations which exercises of this sort exact, that artistic draughtsmanship is best acquired. Drawing thus becomes to the student not a mere mechanical exercise of hand and eye, but a means of expression, — a language by which to convey the architectural idea he has conceived in his mind.

The plans, sections and elevations which the class exhibit as the result of these two months' work are confidently presented in vindication of these views. They are in great part the work of students who had begun the study of architecture six months before. About half the class accomplished this work. The rest, who through absences or from other causes, were not strong enough to undertake it, have spent the time in exercises more suited to their condition.

Hitherto the classes in Architecture had consisted entirely of Special Students in this Department, most of whom had had no previous connection with the school. This year, however, two Regular Students presented themselves, young men, that is to say, who had been through the first two years' course, passing

all the required examinations, and who proposed to take, along with their architectural work, the further scientific studies requisite for a degree. This they have satisfactorily accomplished, and although they have not, of course, done as much Architectural work as the students who could give all their time to it, they have kept up with the class, and have constantly shown the value of the preliminary training the earlier years of the school had given.

The work of the Regular Course thus gone over, in connection with the Departments of Engineering, has comprised the elements of the Differential and Integral Calculus, and their application to Statics and Dynamics, illustrated by work in the Physical Laboratory, consisting of about a dozen practical problems in Friction, the Resolution of Forces, and the Deflection of Beams under various kinds of strain. These students have also done seventeen problems in Stereotomy, with the necessary drawings, and had instruction in Electricity and Magnetism, besides keeping up their exercises in French, German and English.

The Scientific studies of the Fourth Year will be less numerous, and will give Regular Students in this Department more time for their professional work. It will embrace a series of exercises in the Physical Laboratory, specially desired to illustrate architectural problems, and a course of lectures upon Building Materials, Mortars and Cements.

This development of our work promises to be a permanent one, several students of the present Second Year having signified their intention to become regular students in Architecture in the autumn.

The history of the last year was marked by an incident of special interest in the meeting in Boston of the Fifth Annual Convention of the American Institute of Architects, which, by invitation of the Institute of Technology, was held in the rooms of this Department. The opportunity of seeing so large a number of men, eminent in the profession, from different parts of the country, and of listening to their discussions, was keenly

enjoyed by the students. The Convention, in adjourning, besides making their acknowledgments for the courtesies extended to them, signified in strong terms their satisfaction and pleasure in observing the scheme of Architectural Education the Institute of Technology had set on foot.

The work of these four years, though in great part tentative and experimental, and full of the deficiencies that come from limited resources and limited experience, has not been without its good results, and has been highly encouraging for the future. At the present moment, it may be claimed that the Department has fairly established itself in the confidence of the profession and of the community, and it may count upon a constantly increasing support and more extended usefulness. It is as yet too early to say how many students will be in attendance another year; but there is no reason to look for any diminution of numbers. On the contrary, the number who have already entered their names, and the frequent applications for information from students and architects in different parts of the country, seem to justify the expectation of a considerable increase. There is no doubt that we are better able than ever before to meet the reasonable expectations of the profession, and to furnish the instruction and discipline, of every sort, that an architectural education implies.

In this respect the proposed establishment in the School, of Post-Graduate courses of study, will be of special advantage to this Department, enabling us at the same time to extend the range of our work and better to arrange and classify it. As the professional work in the other Departments of the School is accomplished during the Third and Fourth Years, we have hitherto, in order to conform to them, had to set down the arcbitectural work also, under the form of a two years' course; but to give notice that hardly in any instance could two years suffice to complete it. The extension of the period of study for an indefinite term after the regular course is finished will relieve us from this embarrassment. It will now be possible by exacting a certain amount of vacation-work and somewhat

diminishing the work set down to be done in connection with the classes in Civil Engineering, to give the regular students of these two years a sufficient knowledge of the elements of Architecture not to discredit the school — not enough to make them architects, even in the sense in which their fellows become at once Chemists and Civil Engineers, — but enough for Bachelors of Science, enough to enable them to pursue their further studies, in offices and in this Department, to the best advantage. This undergraduate work will thus be complete in itself, including all that relates to the scientific basis of the profession, giving all that an architect needs to know of Mathematics, Chemistry, Physics, Geology and Engineering, with as much of Architectural Drawing and of Architectural Design as can reasonably be comprised within the regular curriculum of a school of science.

The Post-Graduate course will then take up such special scientific topics as may prove desirable, with something of Practice; but it will be chiefly occupied with advanced work of composition and design, in continuation of that begun in the Third and Fourth Years. This work is perhaps more germane to a school of Art than to a school of Science. But it is a work greatly in demand, and one which we may ourselves take in hand with great advantage to our own undergraduates, to more advanced students, wherever trained, and to the community.

By the study of Practice is meant a systematic discussion of professional and business matters, such as contracts, specifications and working drawings, and the relations of architects to their clients and to their workmen. These topics are obviously, in the main, better suited to advanced students than to beginners, and a class fitted to take it up can go over this ground to very great profit in a limited period of time.

But for the main work of the Post-Graduate course, the study of Architecture as a branch of the Fine Arts, no period of time can be fixed, and no special curriculum assigned. Architecture in this aspect is not an exact science, and the methods appropriate to a school of science are less pertinent to this part of the

work than those of a school of art. Still it may be possible, without attempting to set any limit of time, nor to fix upon any course of study as in itself sufficient, to prescribe certain tests of attainment, as is done at the Ecole des Beaux Arts, by which the further honors of the school shall be governed. Just what these honors shall be, and by what rules they shall be awarded may best be left for time and experience to determine..

Such a course of architectural study, beginning with the preparatory work of the Undergraduate course, and extending in the Post-Graduate course over an indefinite period, should be made available, not only for the regular and special students, but for draughtsmen working on half time, or by intermittent and temporary engagements, in the architects' offices of the city. The great advantage to the school of securing such a class of students is obvious, and they should be received on such terms and for such periods as may best suit their necessities. Their work would naturally exhibit a seriousness of purpose and a command of resources that could not fail to act as a powerful stimulus upon their juniors, and to affect in the most favorable manner the tone of the school and its whole standard of performance. It is in this way, moreover, that the Department can best profit by the advantages of its position, in being established in a community where the practice of architecture is so excellent in respect both of construction and of design, and where the character of the profession is so respectable in point both of ability and of attainments. A practical familiarity with the work of the profession, which no schooling of course can give, must needs be sought in a good office, while the best discipline of an office needs to be supplemented by an academic training. If, by coming to Boston young men can combine both opportunities, and thus, in time, earn enough to pay their expenses as they go along, without foregoing the work of personal culture, they will not be slow in any part of the country in finding it out. To young men already well advanced in their professional studies,

the advantages of such an opportunity will hardly need to be insisted upon.

And in no other way, it seems to me, can we meet the reasonable expectations of the friends of the school, answer the higher demands of the profession, and do justice to our own position and resources. Architects so much need draughtsmen and assistants of all sorts that our students are constantly drawn off into office-work before we have begun to show what we can do with them. But we are prepared to give a first-rate architectural education, and the profession and the community are eagerly demanding young men who have received it. By enabling practicing draughtsmen to attach themselves permanently to the school, working upon an advanced class of problems during such leisure as they can command, during a term of years, the Department may hope to meet this want, and to vindicate its claims to a place among the agencies of a superior culture.

As time goes on and our needs are defined by experience, the deficiencies of our equipment in respect both of books and of models, begin to be keenly felt. It is very desirable that some regular provision should be made for supplying from year to year what proves to be most needed. The constantly increasing collections of the Engineering Departments are indeed of great service to us, especially in respect of Descriptive Geometry and Stereotomy, and the Trustees of the Public Library, in opening it to our students, and in promptly buying such new books as may be asked for, have given us every advantage which we could obtain from a library of our own. The establishment of the Museum of Fine Arts, also in the immediate neighborhood of the Institute, will presently put at our command extensive collections of works of art of every kind. But besides these resources we need to have certain things close at hand, in daily service. Books for consultation and constant reference, freely accessible to the students, are our most present want, and the more manifest deficiencies of all our collections need to be made good, and recent productions added. The generosity of the friends and patrons of

the school is, however, constantly doing much to relieve these wants, and the collections have considerably increased since their formation by various voluntary contributions. The most conspicuous of these additions is the stained glass, which has been partly purchased, but is in chief part the gift of the makers. It is arranged in four movable screens, and comprises work by Messrs. Morris & Co., Lavers, Barraud and Westlake, Heaton, Butler and Bayne, Clayton and Bell, J. T. Lyon and G. E. Cook in London, Cottier in Glasgow, and Cook and Mac Donald in Boston, besides some fragments of mediæval windows. Messrs. Maw & Co., of Brosely, Salop, have sent us four large squares of their mosaic and encaustic tiles, suitably mounted for exhibition, besides numerous smaller specimens, to which have been added a considerable number of painted tiles, chiefly by the glass-stainers just mentioned. We have also received from Dr. Salviati a gift of a capital specimen of his revived manufacture of Venetian glass mosaic, for which and for many other benefactions we are indebted to the good offices of Mr. R. P. Spiers, of London, one of our constant friends. Among other additions to the collections may be mentioned a complete set of the photographs of the original designs for the Law Courts in London, and a cast of the head of Michael Angelo's David at Florence, presented by Mr. Edward Atkinson. Mr. C. F. Shimmin has given us an early set of Hancock's reduced restorations of the friezes from Phigaleia and from the Parthenon. Mr. Hatfield and Mr. Wight also, architects of New York, sent us, on returning from the Convention in November, valuable additions to our stock of working drawings and specifications. Besides occasional purchases, our stock of books has been increased by a set of fourteen volumes of the "Illustrated London News," presented by Mr. F. H. Jackson, and the first seventeen volumes of the "Builder," by Mr. J. C. Hoadley.

We have also received an interesting collection of drawings, illustrating the system of black-board instruction in use in the public schools of Belgium, presented to the Institute by the municipal authorities of the Commune of St. Josse-ten-Noode,

Brussels, through Mr. Hendrickx, the originator of the system. The Trustees of the Boston Athenæum have also deposited with us, on loan, a number of casts of architectural details and models of buildings; and the Trustee of the Lowell Institute has, in like manner, given us the use of a large collection of lecture diagrams, a valuable addition to our resources in this particular, which, though constantly growing, are as yet far behind our needs.

Among the most interesting objects upon our walls have been the works of the students themselves, which have been regularly hung in the Eastern or Green Room, under the French drawings, remaining there until displaced by their successors. Some of the best of them have been photographed before being returned to their authors, with a view of forming a porte-folio of students' works.

These various subjects have not only been of service to ourselves, but have been freely used in the cause of art education, wherever, in the present deficiency of such appliances, they have promised to be useful. Especially in the evening drawing classes, recently established in Boston and other towns, and which have to a considerable extent depended for teachers upon the students in this and other departments of the School, they have done excellent service.

The whole undertaking has proved more arduous than it seemed at first, and constantly grows more and more difficult as we enter upon its higher paths. But from the point we have now reached we see more clearly the dangers we have escaped as well as the difficulties of the road before us, and the degree of success which, in spite of all shortcomings, has attended the efforts already made, is the best possible encouragement for the future.

The best work, of course, that a school can do is to discover and develope first-rate talent and to turn it towards the work for which it is best fit, and it is the aim and ultimate hope of this Department to attract the attention of young men of superior capacity, so to arrange its methods of instruction

as to stimulate their best efforts, and thus constantly to recruit the ranks of the profession with highly gifted, as well as with well-trained workmen. It is as yet too soon to say what measure of success may be reached in this regard, but the rapidly extending knowledge of the elements of art among all classes may justify the expectation that whatever germs of artistic power may exist in the community will be brought to light, and this Department may hope to do its part in their training. There is already reason to believe that we are not behind other nations in the quality of our raw material. The quality of our products will depend on the perfection of our educational processes.

I am, very respectfully,
Your obedient servant,
WILLIAM R. WARE,
Professor of Architecture.

REPORT ON THE INSTRUCTION IN STEREOTOMY AND MECHANICAL ENGINEERING.

To the President of the Institute:—

The instruction in Stereotomy is given by lectures illustrated by diagrams and models, combined with practical exercises in drawing and modelling. It is furnished to the students in Engineering and Architecture, and comprehends the making of such plans, elevations, sections, patterns, and working drawings as are essential for the erection of structures in masonry, wood, and iron.

MASONRY AND STONE CUTTING.

The instruction in masonry and stone cutting includes the study of arches of various forms and positions, as cylindrical, conical, and warped arches; full centered, segmental, and elliptical arches; right, oblique, and rampant arches. The structures illustrating this part of the course have included portals, niches, corbels, groined, and cloistered arches, domes, stair-cases, and oblique bridges.

DESCRIPTIVE GEOMETRY.

Exercises in the more difficult parts of descriptive geometry have occasionally been introduced to facilitate and ensure the employment of exact methods.

MODELLING IN PLASTER OF PARIS.

Sets of modelling tools are provided and practical exercises in modelling have been given; these consisted in executing from rough pieces of plaster, models of portals, oblique, and rampant arches, with the aid of patterns and drawings previously prepared by the students themselves.

It may not be out of place to state, that although this kind of modelling is taught in the European schools of engineering, no attempt has hitherto been made to teach it in this country.

Moulding in plaster has been taught to a limited extent.

STRUCTURES IN WOOD AND IRON.

The instruction in carpentry includes framing, bay work, the construction of roofs, etc. Examples of Mansard roofs, of English roofs, showing the combination of iron with wood, ensuring strength and durability; and the most approved forms of iron roofs according to the system of Polonceau, have been given.

Problems in construction and design, accompanied with numerical data, have been given to exercise the ingenuity of the student, and put to a practical test his acquired knowledge and skill.

GRAPHICAL WORK.

Graphical exercises have been given to each student beginning with an exercise in descriptive geometry as follows:—

PROGRAMME OF THE FIRST PROJECT IN THE APPLICATION OF DESCRIPTIVE GEOMETRY TO THE ARTS.

Intersection of a Surface of Revolution by a Plane.

A torus, the radii of whose generating and directing circles are respectively r and R, and the distances of whose centre from the planes of projection a and b, is intersected by a plane. This plane has a declivity t; its horizontal trace making an angle α with the ground line, is at a distance d from the axis of the torus. (a = distance above H.P. b = distance in front of V. P.)

The students will present,

1st. A drawing containing the two projections of the intersection of the plane with the torus, with one or more tangents to the limiting curve. The section should be colored according to the conventional tint.

2d. A drawing containing the curve and its tangents in their own plane.

3d. A memoir, explaining fully the principles and processes of the solution, the method in detail for tracing upon the solid in relief the curve of intersection, for cutting the solid, and for testing the accuracy of the section. [The pattern for verification should be constructed from the 2d drawing.] The students will use the following numerical data in alphabetical order.

R=	2·16	2·24	2·32	2·16	2·24	2·32	2·16	2·24	2·32
r=	1·12	1·20	1·28	1·28	1·20	1·12	1·20	1·12	1·20
α=	45°	46°	47°	48°	49°	45°	46°	47°	48°

t = 0·5 a = 2·00 b = 4·00 d = 4·00

This exercise is varied by substituting for the plane or the torus, or both, developable, double curved, or warped surfaces.

Then follow the exercises in masonry and stone cutting executed by each student.

Each drawing contains the plan, elevation, profile, section, and development (if possible) of the arch, with the patterns of the joints.

These exercises are as follows: —

1. Right cylindrical arch.
2. " portal in a battering wall.
3. Full centered oblique portal.
4. " " portal in a round tower.
5. Spherical niche.
6. Solid corbel (known by the name of *Trompe.*)
7. Vaulted conical portal.
8. " portal (known as *Arrière vousure de Saint Antoine.*)
9. " portal (" " " " *de Marseille.*)
10. Groined arch.

11. Cloistered arch.
12. Dome.
13. Exercise to illustrate the properties of the warped surfaces.
14. Spiral staircase.
15. An original exercise with numerical data, illustrating the intersection of one arch with another of a different size.
16. Oblique bridge. Helicoidal System.
17. Rampant arch.

EXERCISES IN MODELLING.

The students this year have made three complete models:

1. A vaulted conical portal.
2. A rampant arch.
3. An oblique arch.

EXERCISES IN CARPENTRY.

1. Construction of a Mansard roof.
2. Construction of an English roof, illustrating the combination of wood with iron.
3. Bay work.
4. Construction of an iron roof according to the system of Polonceau.

[This last problem has not yet been completed.]

MECHANICAL ENGINEERING. — THIRD YEAR. — FIRST TERM.

The instruction in Mechanical Engineering commences with Cinematics, or the study of motions as exhibited in machines, and treats of the composition and resolution of such motions, and their graphical representation by means of curves, which serve to show the spaces, velocities, accelerations, and paths of the moving points or pieces. Applications of these principles

are at once made in the construction of cams and sliding pieces. Next, the properties of rolled curves, with the exact and expedetive methods for their delineation, are explained and applied in the construction of all kinds of gearing.

PRINCIPLES OF MECHANISM.

The principles of mechanism are next taught according to the system of Willis. The study begins with simple elementary combinations, and is extended so as to include the various contrivances for modifying the motion or the path of a moving piece, such as epicyclic trains, parallel motions, speed cones and pulleys, universal joints, link motions, etc., etc.

A recent examination paper is here introduced to illustrate the instruction, which varies from year to year as improvements suggest themselves.

SEMI-ANNUAL EXAMINATION. THIRD YEAR.
CINEMATICS.

1. *Helical motion.* Investigate the motion of a body rotating around a given axis, and moving at the same time parallel to this axis.

Example. A body makes 40 revolutions per minute, and has at the same time a velocity of translation $4\frac{1}{2}$ times its angular velocity. Determine the trajectory, as well as the direction and velocity of a point 6 ft. from the axis of rotation.

2. *Combined Parallel Rotations.* Let a plane passing through a fixed axis O, rotate about it with a given angular velocity a. Let C be a second axis in that plane, and parallel to the fixed axis O; and about the moving axis C, let a rigid body rotate with an angular velocity b relatively to the plane OC. Show how to find the position of the instantaneous axis and the resultant angular velocity.

3. *Curvature of the Epitrochoids.* Deduce the radii of curvature of the following curves employed in the construction of the teeth of wheels:

The Epicycloid, the Trochoid, the Cycloid, the Involute of the Circle, the Archimedian Spiral.

4. *Rotations about Intersecting Axes Combined.* Let OA be an axis assumed as fixed, and about it let a plane passing through OA

rotate with an angular velocity a. Let OC be a second axis in that plane and intersecting the first axis at O; about the moving axis OC let a rigid body rotate with an angular velocity b. Show how to find the position of the instantaneous axis, the surface it describes, and the resultant angular velocity.

Bevel Wheels. Two axes intersecting at an angle of 80° are to be connected by a pair of bevel wheels: one axis is required to make three revolutions to one of the other. The largest radius of the pinion is 12 in.; this pinion is to have 44 cast iron teeth. The teeth of the wheel are to be of wood, and the width measured along the pitch surfaces is to be 5 in. The profiles of the teeth are to be involutes of the circle; and finally there must always be at least one pair of teeth on the first in contact with a pair on the second wheel. Show how to lay out the teeth.

5. *Combined Rotation about Axes not in the same Plane.* A rigid body rotates with an angular velocity p, around a given axis A in space; this axis revolves around a second given axis B, not in the same plane with the first, with an angular velocity q. Required the resultant angular velocity, the position of the instantaneous axis, and the surface it describes.

Skew bevel Gearing. It is required to connect two perpendicular axes not situated in the same plane by a pair of skew bevel wheels. The shortest distance between the axes is 12 in.; the least diameter of the pinion must be 24 in.; it must have 72 teeth 6 in. in width, measured along the pitch surface. The profiles of the teeth are to be formed by epicycloids and hypocycloids.

6. *Non Circular Wheels.* What are the geometrical conditions that must exist between a pair of rotating surfaces, in order that they may move in rolling contact round fixed axes?

Example. The equation of the base of a cylinder rotating around a fixed axis is log. $r = A\,\theta + B$; what must be the equation of the base of a second cylinder rolling in contact with the first and rotating around a second fixed axis.

7. *Sliding of Teeth.* Given the arcs of approach and recess, to find the amount of sliding of one tooth over another.

8. *Sliding of Involute Teeth.* Find the amount of sliding of two involute teeth, supposing the tangent to the base circles to make an angle of $75\frac{1}{2}°$ with the line of centres.

9. *Adendum of Involute Teeth.* Show how to find the adendum for involute teeth.

10. *Swash-Plate.* Find the equation expressing the motion transmitted by the swash-plate.

Show how to make a cam which will give the same motion.

11. *Cams.* Show how to construct a cam which shall give any assigned motion to a moving piece. Given $s = f(t)$.

Example. Make a cam which shall give exactly the motion of an eccentric.

MECHANISM.

12. *Wheels in Trains.* Suppose two axes are to be connected, whereof one revolves once in 24 hours, and the other in 362 days 5 hrs. 48 min. 48 sec., show how to arrange the train.

13. *Screw-Cutting Lathe.* What train should be used upon a screw-cutting lathe with a guide screw of $\frac{1}{2}$ an inch pitch, to cut a screw with $13\frac{3}{4}$ threads to the inch?

14. *Least number of Axes.* Given the value of a train, the least number of teeth allowed upon a pinion, and the greatest number allowed upon a wheel, to find the least number of axes.

Example. Required the least number of axes in a train of wheels which shall cause the last axis to revolve 180 times as fast as the first axis, allowing that none of the drivers contain more than 54 teeth, and none of the followers less than 9.

15. *Epicyclic Train.* Deduce the general formulæ for finding the value of epicyclic train.

Example. Ferguson's Paradox.

16. *Parallel Motion in Gorgon Engines.* Explain the theory and construction of the parallel motion used in a certain class of marine engines, known as Gorgon Engines.

The above instruction is completed in four months, and is followed by a course on the dynamics of machinery.

DYNAMICS OF MACHINERY. — THIRD YEAR — SECOND TERM.

This comprehends the estimation and measurement of force and power; the application of the principles of virtual velocities to machines; the theory and use of the indicator and dynamometer; the estimation of the effects of centrifugal force; the determination of the safe speed of rotation for fly wheels, mill stones, polishing stones, etc.; the method of balancing locomotives to prevent dangerous oscillations when running at high speeds; the estimation of the effects of fluctuations of speed; the study of regulating apparatus, as fly-wheels, governors, cataracts, brakes, etc; the computation of the loss of power due to secondary resistances; resistance of friction; estimation of the loss of mechanical effect, occasioned by the friction of journals, pivots, teeth, screws, cords, belts, chains, etc.

To illustrate this last important subject, a powerful machine is taken and the loss of power on account of the friction of each piece is successively calculated, and the efficiency of the whole machine deduced.

GRAPHICAL WORK.

The instruction in making sketches and finished drawings of machinery from models, and from actual machines is continued during the third year, but in addition to this, numerical and graphical problems pertinent to the subjects of the lessons are given from time to time: such as the construction of cams, excentrics, link and valve motions, and all kinds of gearing.

This is followed by exercises in drawing complete machines from given numerical data. For this purpose, liberal use is made of the collection of models belonging to this department.

At end of the year an examination over the whole course is held. The following is an examination paper:

ANNUAL EXAMINATION—THIRD YEAR.

MECHANISM.

1. *Epicyclic Trains.*

Deduce the general formulæ for finding the value of an epicyclic train.

Example.—Explain the *differential motion* of the bobbin and fly frame, in cotton spinning machinery, and calculate the velocity ratios of the bobbin and the flier corresponding to several different positions of the belt upon the speed cones.

2. *Watts' Parallel Motion.*

Explain the theory and construction of the parallel motion used in beam engines, or in side lever marine engines.

3. *Boring Machines.*

Explain the machinery used for boring steam cylinders.

Example.—Show how to arrange a train with the guide screw of $\frac{1}{2}$ an inch pitch, so that the cutter shall advance $\frac{1}{18}$ of an inch for every revolution of the boring bar.

4. *Speed Pulleys.*

Open Belt.—Find the length of an open belt upon a set of speed pulleys.

Example.—Let the diameters of two speed pulleys be 4, 6, 8, 10, 12 inches respectively and the distance between their centres 6 ft. Find the difference in length of belt required for the pulleys 12 and 4, and that required for the pulleys 8 and 8.

Crossed Belt.—Find the length of a crossed belt for the above system of pulleys and show that it will fit any pair of the speed pulleys with perfect exactness.

DYNAMICS OF MACHINERY.

5. *Friction of an Axle.*

Example.—A water wheel weighs 30,000 lbs., the radius of its circumference is 16 ft., and that of its gudgeon is 5 in.; how much force is required at the circumference of the wheel to overcome the friction, or to maintain it in uniform motion when running empty, and how great is the corresponding expenditure of mechanical effect when it makes 5 revolutions per minute? Co-efficient of friction 0.075.

6. *Friction of a Pivot.*

Find the moment of friction of a pivot.

1st. General case in which the equation of the longitudinal section is $y = f(x)$.

2d. Flat pivot.

Example.—A Turbine weighing 1800 lbs. makes 100 revolutions per minute and the diameter of the base of the pivot is 1 inch, how much mechanical effect is consumed in a second by the friction of this pivot? Co-efficient of friction = 0.10.

3d. Schiele's anti-friction pivot (Tractrix). Find the moment of friction.

7. *Effects of Centrifugal Force.*

Example.—The dimensions, density, and strength of a mill-stone are given; required the angular velocity and number of revolutions per minute, which will cause rupture in virtue of centrifugal force. Radius of the mill stone 2 ft.; radius of the eye 4 in. Modulus of rupture 720 lbs., specific gravity 2.5.

8. *Fluctuations of Speed.*

Determine the coefficient of fluctuation of speed in a machine.

Example.—The fly wheel of an engine of 35 horse power makes 20 revolutions per minute, its diameter is 20 ft., and its weight 20 tons. If the engine were employed to lift a tilt hammer weighing 4000 lbs., the centre of gravity of which is raised 3 ft., and if this were done merely by the work accumulated in the fly wheel what part of its angular velocity would it lose?

9. *Rankin's Isocronous Gravity-Governor.*

Find the relations between the dimensions, the revolving mass, the load and the speed.

10. *Efficiency of Teeth.*

Find the efficiency and counter-efficiency of a pair of spur and a pair of bevel wheels.

Example.—A force of 912 lbs. is applied to the circumference of a pair of spur wheels having 221 and 111 teeth respectively. The co-efficient of friction is 0.10. What is the counter-efficiency and what force is transmitted to the second wheel?

FOURTH YEAR.—FIRST TERM.

The instruction comprehends:—

The examination of the materials used in Machinery, viz.: iron, steel, other metals and their alloys, wood, leather, hemp, etc.; their uses, defects, and the methods of preserving them from rust and decay; their moduli or coefficients of strength, elasticity and stiffness.

RESISTANCE OF MATERIALS.

This includes the estimation of the strength and stiffness of pieces exposed to tensile, shearing, bending, and twisting strains; factors of safety; calculation of the strongest forms of pieces; practical approximations to these; the effects of shocks and vibrations; the estimation of the strength of structures of stone, wood, and iron, as foundations, beams, columns, roofs, etc.; theory of continuous, and bowstring girders.

This portion of the course, which is thoroughly illustrated with practical examples, is followed by the students of Architecture, as well as those of Mining and Mechanical Engineering.

SEMI-ANNUAL EXAMINATION.—FOURTH YEAR.—COURSES I, III, IV.

1. *Extension.* Deduce the general formulæ for extension and compression, and solve the following problem:—

What must be the upper cross section of a wrought iron beam of the strongest form, 1000′ in length, when, besides its own weight, it has to sustain a load of 75,000 lbs.?

What will be the elongation?

Modulus of Tenacity, T = 10,000 lbs. Modulus of Elasticity = 29,000,000 lbs. Weight of inch bar wrought iron per running foot = 3.34 lbs.

2. *Resilience.* Compute the work necessary to extend or compress a given beam or shaft.

Example. The pumping apparatus of a mine is connected with the engine by means of a series of wrought iron rods 200′ long;

the section of each rod is $\frac{8}{4}$ of a square inch; the strain is estimated at 6 tons. How many units of work are expended at each stroke in the elongation of the bars? Modulus of Elasticity = 29,000,000 lbs.

3. *Flexure and cross breaking.* Investigate the case of a beam built in at one end, supported at the other, and uniformly loaded.

4. Apply the foregoing investigation to the theory of *continuous girders*, and solve the following problem:

A wooden beam 40′ long, bearing a load of 500 lbs. per running foot, rests upon three equidistant supports, what must be the dimensions of the beam? Modulus of working load 1000 lbs.

5. *Compression.* If in the last example the centre support were a wooden post, what should be its diameter if the modulus of rupture be 6500 lbs., and a six-fold security allowed?

6. *Torsion.* Deduce the formulæ to determine the strength of shafts to resist torsion.

Example. The cast iron, upright axle of a turbine exerts at the circumference of a cog wheel, 30″ in diameter, keyed to this axle, a force of 2500 lbs. What diameter must be given to the shaft? Modulus of rupture 27,000 lbs., and a six-fold security to be allowed.

7. *Timbering in a mine.* At what distance from each other must the 10″ stretchers be laid to support a pile of refuse 60′ high of an over hand stope, in a vein 4′ thick, and dipping at 70°? The weight of a cubic foot of material to be supported is 65 lbs.; the coefficient of friction upon the supports is $\frac{1}{3}$.

8. *Calculations for the establishment of a bowstring girder.* A bowstring girder, consisting of two beams 12′ long, 4″ high and 12″ wide, with diagonal braces and vertical struts, is supported at the extremities and loaded in the middle; the greatest opening between the beams is 10″.

What is the moment of flexure of the *upper beam* unloaded, caused by the middle strut?

What is the radius of curvature of its mean fibre, and the relative elongation of the extreme fibre?

What is the radius of curvature of the *mean fibre of the girder*, and its relative elongation?

What weight will the girder bear with safety? Modulus of strength = 12,000 lbs., and a three-fold security allowed.

Compute the increase in strength due to the struts and bracing.

The following additional questions were given to the class in Mechanical Engineering.

9. *Strength of an axle.* A round, wooden axle of a water wheel, 10′ long, has to sustain the wheel together with its own weight, and a uniformly distributed load of 10,000 lbs. What diameter must the axle have? Modulus of strength 10,000 lbs., and a ten-fold security to be allowed.

10. *Limit of speed.* Given the radius and section of the rim of a fly wheel, it is required to find the number of revolutions per minute, which will cause rupture from the action of centrifugal force. How many revolutions per minute can it make with safety?

11. *Dimensions of fly wheels.* Given the energy stored in a fly wheel, the number of revolutions per minute and the weight of the rim, to find the mean radius and section of the rim.

12. *Strength of gear wheels.* Given the radius of the pitch circle of a gear wheel transmitting N horse power, and the number of revolutions per minute. Show how to calculate the pitch, number of teeth, their dimensions and those of the rim.

13. *Effect of fluctuations of speed.* The fly wheel in a rolling mill is connected with the rolls by a pair of spur wheels. At the instant at which the blooms pass under the rolls (according to the experiments of Morin), a fluctuation of speed occurs of one-thirtieth, which lasts about one-seventh of a second. Suppose the number of revolutions of the fly wheel to be 70 per minute; let the energy stored in its rim be estimated at 3,600,000 ft. lbs., what would be the pressure thus occasioned on the teeth of one of the spur wheels, having a radius of 3 ft. 8 in,, and situated on the same shaft as the fly wheel?

FOURTH YEAR. — SECOND TERM.

CONSTRUCTION AND ESTABLISHMENT OF MACHINES.

This comprehends: —

The calculation of the strength, the requisite proportions and dimensions of the parts of machines, viz., those exposed to shearing stress, as rivets, pins, keys, wedges, gibs, cottars, bolts,

screws, etc.; those exposed to tensile strain, as cords, bands, rods, links, etc.; those exposed to shocks, and combined bending and twisting actions, as shafts, journals, cranks, rims, arms, teeth, etc.; the computation of the straining effects due to the power; allowance for the centrifugal tension of bolts, of wheels and pulleys; centrifugal whirling of shafts.

To illustrate this part of the course a powerful machine is selected, and the calculations made to determine the stress upon each piece, and the proper proportions and dimensions which should be given to it.

THE PRINCIPLES OF THE ACTION OF CUTTING TOOLS.

Description of shearing, paring and scraping tools; proper angles and speed for different kinds of work; estimation of the work done in dynamical units; combinations of cutting tools; advancing and transverse feed motions; machine tools — punches, lathes, drills; planing, slotting, shaping machines, etc.

ANNUAL EXAMINATION FOURTH YEAR.

CONSTRUCTION OF MACHINES.

1. *Straining effects of Reaction.*

Example.—A piston and its appendages weigh 300 lbs., the length of the crank is 15 in., the number of revolutions per minute is 60. Required the straining effect due to the accelerating force of the steam on the piston.

2. *Strength of Belts. Centrifugal Tension.*

Example.—Suppose a belt moving over a suitable pulley with a velocity of 600 ft. per miuute, transmits a work of 5 horse power. Required the centrifugal tension, tbe tension due to the force transmitted, and the proper width of the strap.

3. *Strength of Axles.*

Example.—The crank at the end of a shaft receives and transmits a work of 50 horse power; this shaft rests upon two bearings 6 ft. apart, and carries one of a pair of spur wheels; this wheel situated at a distance of 5 ft. from the journal next the crank, weighs 3000 lbs., makes 35 revolutions per minute, and has a diameter of 14′ 8″. Find

the proper dimensions of the journal next the crank, taking into account; 1st, the force transmitted; 2d, the weight of the wheel; 3d, an approximate value for the weight of the axle; 4th, the reaction of the teeth of the wheel against its pinion. Show whether at this velocity the oil will be decomposed by overheating. Show also whether the pressure between the surfaces in contact is sufficient to expel the oil.

4. *Transverse Vibration of Pieces.*

Example.—1st. A pine rod 1 centimetre square, supported at two points 1 m. apart and loaded by a weight of 1.37 k. is deflected 0.032 m. What is its modulus of elasticity?

2d. The same rod was then loaded at the other end with a weight of 0.321 k. and put in vibration. The number of single vibrations in 30 seconds was 100. What was the modulus of elasticity?

ACTION OF CUTTING TOOLS.

5. Determine the pressures and the work performed by shearing and cutting tools.

Example.—What force does a punching machine exert in punching a hole through plate iron $\frac{1}{2}''$ thick, for a rivet $1\frac{1}{2}''$ in diameter? What amount of energy is expended? $f = 50{,}000$ lbs.

6. *Resistance and Work of Paring Tools.*

Compare the work of the machine with that of lifting the materia pared off.

HYDRODYNAMICS.

7. *Impulse of Water on Vanes. Flat Vane.*

Example.—A stream of water whose cross section is 40 square inches, delivers 5 cu. ft. per second, and strikes normally against a flat vane, which moves away with a velocity of 12 ft. What is the impulse? The mechanical effect? What velocity must the vane have to produce the maximum effect? Required the mechanical effect, the pressure, and the efficiency due to this velocity.

HYDRAULIC MOTORS.

8. *Poncelet's Floats.*

Describe and give the theory of Poncelet's floats.

9. *Floating Mill Wheels.*

Find the mechanical effect of a wheel in an open current.

10. *Turbines.*

Give the theory of the turbine; compute the energy exerted by the water on the wheel, the energy expended, and the efficiency of the motor.

COURSE ON THE STEAM ENGINE AND OTHER PRIME MOTORS.

This course is given to all the students in Engineering, and comprehends the measurement of force and power; the theory and use of the indicator and dynamometer; the estimation of the resistance of friction in machines, and the principles of hydraulics pertaining to the construction of hydraulic machines and motors.

PRINCIPLES OF HYDRAULICS.

These comprise the measurement of water power; the computation of the discharge over weirs, through orifices and sluice gates; the estimation of the resistance in pipes due to friction, bends, mouth pieces, etc.; the calculation of the mechanical effect due to the impulse of water upon vanes of various forms, and moving in directions oblique to the jet; the computation of the speed of the vane to give the greatest efficiency; the best form of vane to receive a jet; the effect of friction during the impulse; the effect of centrifugal force.

HYDRAULIC MACHINES AND MOTORS.

The description of each hydraulic machine illustrated by models and diagrams; the theory of its action, and the calculation of its efficiency. These machines include the hydraulic press, single and double acting water pressure engines, water wheels, floating mill wheels, turbines, reaction wheels, etc.

PNEUMATIC MACHINES.

The description, theory, and the calculation of the efficiency of machines accumulating or using power by means of com-

pressed air; as the Chemnitz machine, the compressing pumps and engines employed in tunnelling Mt. Cenis, etc.

PROPERTIES OF STEAM AND GAS. — EFFECTS OF HEAT.

The results of Regnault's and Fairbairn's researches on the relations between the temperature, pressure, and specific volume of saturated steam; the results of Zeuner's researches on superheated steam; the computation of the loss of heat by radiation, according to the experiments of Peclet; the effect of jacketing; the computation of the heat thus economized per hour; the calorific power of different kinds of fuel; the total and available heat of combustion; the quantity of air required for combustion and dilution.

BOILERS, FURNACES AND FIRE GRATES.

The description and general arrangement of a furnace and boiler; the strength and construction of boilers; the total and effective heating surface; the water and steam room; the computation of the dimensions of a boiler to produce a certain quantity of steam per hour at a given pressure; the efficiency of a furnace; the efficiency of the heating surface; the requisite amount of grate surface.

STEAM AND GAS ENGINES.

The estimation of the work of the steam in an expansive steam engine: 1st, when the pressure is supposed to vary according to Mariotte's law; 2d, when the pressure is supposed to vary according to Laplace and Poisson's law; the efficiency of different kinds of engines; the estimation of the quantity of steam, feed water, and fuel, requisite to supply an engine running at a given speed with a given pressure of steam; the calculation of the effective work on the crank shaft; the theory of the slide valve, (Zeuner's graphical method); the expansion valve; the gas engines of Lenoir and Hugon; the recent improvements in this direction, with the binary steam and vapor engines.

This course has been illustrated throughout with numerical examples.

The following examination papers of last year are annexed:

MACHINERY AND MOTORS.—FIRST EXAMINATION FOURTH YEAR.

MEASUREMENT OF THE DYNAMIC EFFECT OF MACHINES.

1. *Dynamometer.* Explain the theory of Proney's friction dynamometer, and apply it in the solution of the following problem:

To determine the effect of a water wheel, a friction dynamometer was placed on the shaft when the water let on had been perfectly regulated for six revolutions per minute; the weight in the scale pan, including the reduced weight of the instrument, was 530 lbs., the leverage of this weight was 10.5 ft. What was the horse power of the wheel?

2. *Indicator.* Explain the theory of the indicator, and apply it in the solution of the following question:

A double acting expansive steam engine has two indicators, one at each end of the cylinder. The breadths of the diagrams given by each, measured on a scale representing pounds on the square inch, are as follows:

Top, 27, 83, 91, 91, 64, 57, 53, 42, 35, 22, 13; bottom, 36, 97, 96, 84, 64, 57, 46, 40, 32, 22, 12; the area of the piston is 345 square inches; the length of stroke is 30 inches; the number of revolutions per minute is $52\frac{1}{2}$; what is the indicated horse power of the engine?

3. *Brake.* Explain the theory of the flexible brake, and apply it in the solution of the following question:

To let down a shaft a load of 1200 lbs. from a certain height, the rope to which this weight is attached is wrapped $1\frac{3}{4}$ times about a round, firmly clamped holder, and the other extremity is held by the hands; with what force must this extremity be stretched that the load may slowly and uniformly descend? Let the coefficient of friction, $f = 0.3$.

HYDRAULICS.

4. *Discharge through a rectangular orifice.* Example. If a rectangular orifice is 3′ wide, $1\frac{1}{4}$′ high, and the lower edge lies $2\frac{3}{4}$′ below the surface of the water, what will be the discharge per second?

5. *Friction of the water in pipes.* Example. What discharge will flow through a pipe 2″ in diameter, under a head of 3′ of water, when the coefficient of resistance, owing to the friction in the pipe, is 0.40.

ÆRO-DYNAMICS.

6. *Work of Expansion.* Compute the mechanical effect produced by the expansion of a given volume of air or steam.

Example 1. The inner diameter of the cylinder of a high pressure, double acting steam engine, without expansion, is 18″, the number of revolutions per minute 24, the length of stroke 40″. The steam gauge stands at 32.25 lbs. The barometer indicates the pressure of the atmosphere to be 14.1 lbs. What is the pressure on the piston, and what is the power of the engine?

Example 2. In the last example what would be the horse power of the same engine, working expansively, the steam being cut off at .4 of the stroke?

How much more steam would be used in the first case than in the second?

State the relative economy in using steam expansively.

7. *Compressing Engine.* Make a sketch of the compressing engine (*Compresseur à choc*) used at the Mt. Cenis tunnel for supplying compressed air to the boring machines. Give the theory of this engine, and calculate its efficiency. Diameters of the tubes 0.62 metres; height of the column of air compressed at each stroke 4.05 metres; height of the fall, 26 meters; pressure of the atmosphere 10.330 metres; pressure in the manometer 7 atmospheres after each stroke.

8. *Compressing pump.* Make a sketch of the forcing pump (*Compresseur à pompe*) used for the same purpose. Give the theory of its working, and calculate its relative and absolute efficiency, supposing it to be driven by an overshot water wheel, using 60 cubic metres of water per minute, with a fall of 5.60 metres. Diameter of the pump 0.57 metres; length of stroke 1.20 metres; number of strokes per minute 16; manometric pressure 7 atmospheres. Assume the efficiency of the water wheel to be 75 per cent.

9. *Safety Valve.* Find the effective pressure necessary to open the safety valve and solve the following problem:

The statical movement of an unloaded safety valve is 10 inch lbs.; the sliding weight, 15 lbs., has a leverage of 10″; the arm of the valve measured from the valve to the fulcrum is 4″; the radius of the valve is 1.5″; what is the pressure per square inch on the valve?

HYDRAULIC MOTORS.

10. *Water Pressure Engine.* Calculate the principal parts of a single acting water-pressure engine used to drain a mine.

Given depth of the mine, h = 230 metres; quantity of water flowing in per minute, q = 1.792 cubic metres; source of power, a fall, H = 60 metres, giving a quantity, Q = 20 cubic metres per minute. Loss of head due to friction, bends, valves, etc., $k' = \frac{1}{3}$. Loss of water on account of the pierced valve, $k'' = \frac{8}{10}$. Assume the length of stroke, Z = 2.3 metres; the number of strokes, n = $5\frac{1}{2}$ per minute, and limit the velocity of flow through the supply pipe to 2 metres per second. Calculate also the size of the supply pipe and the diameter of the forcing pump.

11. *Effect of Centrifugal Force.* Effect of the centrifugal force on an overshot water wheel.

Example. An overshot water wheel 32′ in diameter makes 5 revolutions per minute, what angle does the surface of the water in the bucket at the extremity of a horizontal diameter make with a horizontal line?

12. *Poncelet's Water Wheel.* What should be the curve of the longitudinal section of the head race for Poncelet's water wheel?

SECOND EXAMINATION.

HEAT APPLIED TO AIR AND STEAM.

1. *Combination of the laws of Mariotte and Gay Lussac.*

Example.—If 800 cu. ft. of air at a temperature of 10° C., and at a pressure of 15 lbs., are brought by means of the blowing engine and warming apparatus of an iron furnace to a temperature of 200° C., and a pressure of 19 lbs., what volume will it assume?

2. *Specific Volume of Saturated Steam.*

Example.—What quantity of feed water does a boiler require to produce 500 cu. ft. of saturated steam at a pressure of 3 atmospheres?

3. *Specific Volume of Superheated Steam.*

In the last example let the steam be superheated to 150° C, and at the same pressure; what will be the amount of feed water then required?

4. *Peclet's Law of Cooling.*

Example.—A wrought iron boiler contains water at a temperature of 100° C., and has a surface of 15 square mtrs. exposed to the air at 20° C.; what hourly cooling takes placé?

Effect of the Jacket. If the same boiler had a jacket of 25 square mtrs., what cooling would then take place?

CONSTRUCTION OF BOILERS.

5. *Boiler with Heaters.*

Example.—Determine the dimensions of a cylindrical boiler with hemispherical ends to supply 520 lbs. of steam per hour. Let the boiler be furnished with two heaters.

6. *Strength of Boilers.*

Example.—Find the proper thickness of plate iron for the foregoing boiler, on the supposition that the working pressure is to be 4 atmospheres.

THERMODYNAMICS.

7. Apply Poisson's law for the specific heat of gases to determine the work done by the expansion of a given quantity of air, gas or steam; and state what modification the formulæ would undergo for each of these fluids.

Example.—The inner diameter of a high pressure, double-acting, expansive steam engine is 18″; length of stroke is 40″; number of revolutions per min. 24; the steam gauge stands at 65 lbs; the steam is cut off at .4 of the stroke; what is the power of the engine, and how much steam is required per hour?

QUANTITY OF FUEL CONSUMED BY A STEAM ENGINE.

8. A low pressure, non-expansive steam engine has a cylinder 6′ long, and $2\frac{1}{2}$′ in diameter; number of revolutions per minute 18; temperature of the steam 104° C.; temperature in the condenser 35° C.; efficiency of the engine, 0.60. What is the power exerted on the

crank? How much steam is used per hour? How much feed water at 30° C., will be required to supply the boiler? How many units of heat per second will be required to produce this steam? Let the efficiency of the furnace be 0.75, that of the heating surface be 0.60 and suppose 1 lb. of coal to contain 7500 units of heat. How much coal is consumed per hour? How much per horse power per hour?

9. *Expansion slide Valve.*

Example.—The radius of the eccentric is 1.57″, the steam is to be cut off at $\frac{1}{4}$ of the stroke. Compute the breadth of the port in the expansion valve.

10. *Balancing Locomotives.*

Show how to compute the proper weights to balance the centrifugal force in a locomotive.

Example.—Show how to balance an inside cylinder engine of the following dimensions: Distance between the centres of the cylinders = 2′ 6″, distance between the wheels 4′ 7″. Weights of the moving parts; crank referred to the pin 93 lbs.; connecting rod 188 lbs.; piston and rod 174 lbs.; cross head 64 lbs. Distance of the centre of the counterpoises to be 3 times the length of the crank. Determine the weight and position of each counterpoise.

GRAPHICAL WORK: PROJECTS.

Projects for machines and motors are given when the students have been made acquainted with the doctrine of the strength of materials, so as to be able to find the dimensions of pieces to resist flexure, shearing, torsion, etc. They consist of original designs for machines, involving the determination of the strength, dimensions, and proper proportions of the several parts by calculation.

The programme of a project, given during the current year, is here inserted as an illustration of the kind of work accomplished.

PROJECT FOR A TRAVELLING CRANE TO BE USED IN THE CONSTRUCTION OF A STONE BRIDGE.

PART FIRST.

The load is to be moved along the bridge, across the bridge, and vertically.

For this purpose there should be established a line of railway, one rail being placed on each side of the service bridge; upon this track a car with four wheels is to run; the platform of this car should consist principally of two wrought iron hollow beams. Upon this car should be placed a second track, at right angles with the first and laid upon these beams. Upon this second track a second car should be placed carrying a crab engine furnished with a brake, a ratchet and detent.

The present project is divided into two parts. The first consists of a memoir and the sketches requisite for understanding the machine as a whole and in detail. In the memoir the arrangement of the parts should be clearly described, and the dimensions given to the principal pieces verified. Finally, the force necessary to produce each of these three motions is to be calculated considering the effect of friction. 35 lbs. should be the limit to the effort of a man turning a crank.

The traction of the car is two per cent. of the weight. The data are as follows:—

Maximum weight to be lifted	15,000 lbs.
Vertical distance " " "	. 20 ft.
Width of the first track	. 40 ft.

GRAPHICAL WORK: PART SECOND.

The students will make a general plan, an elevation, and a section; also, the details of the transmission of all the motions, the brake, the engaging and disengaging gear, and in fact every thing necessary for the complete comprehension and construction of the machine.

These drawings should be shaded in india ink, and the nature of the materials employed, should be shown by the conventional tints.

The following projects, requiring more or less original research have been done during the present year.

1. Project for an outward flow turbine to drive a cotton mill.
2. Project for a travelling crane to be employed in the construction of a stone bridge.
3. Report on the construction and efficiency of the compressing pumps used at the Mt. Cenis tunnel, for supplying compressed air to the boring machines, accompanied with elaborate drawings.

4. The computation for the construction and establishment of a packing press capable of exerting a pressure of 80 tons.

5. Project for a water wheel according to the system of Poncelet; to be used for driving a flour mill.

6. Project for a rolling mill driven by a steam engine.

7. Project for a parallel flow turbine system according to the system of Jonval, to furnish the power sufficient for a machine shop.

8. Project for a gas engine according to the system proposed by Mr. Brayton.

9. Report on the construction and efficiency of the compressing engine used at the Mt. Cenis tunnel for supplying compressed air to the drills with drawings of the engine and its details.

These projects comprise:—

1. The plans, elevations and sections of the machines.

2. The working drawings of the details.

3. A memoir containing the description and theory of the machines; the estimation of the resistances; the calculation of the strength and proper proportions of the parts, and the reasons for the particular dispositions adopted.

EXCURSIONS.

In aid of the practical studies of the School, the students have made a number of excursions, for the inspection and study of machines. The most recent are as follows:

Feb. 17. To Brayton's Gas Motor:—

The principles, the mode of action, with the details of the construction were explained by diagrams, and illustrated by the practical working of the machine. The analogy between this motor and the common caloric engine was carefully explained, together with the devices employed for substituting for ordinary gas, the vapors of the volatile hydro carbons.

The differences between this engine and those explosive engines of Lenoir and Hugon were pointed out, together with the novel and ingenious application of the principle of Bourdon's gauge for automatically regulating the pressure.

Feb. 24. To the Boston Gas Works to examine the practical working of Hugon's Gas Engine.

The mechanism of the valves and the construction of the interior of the machine were shown by diagrams; the quantity of gas consumed was observed, and the cost of running estimated. The effect of the introduction of a jet of water into the cylinder was exhibited by curves showing the changes in the manometric pressure.

March 2. To Houghton's Automatic Steam Pump. The apparatus was shown by a beautiful glass working model. The analogy between this and Savery's steam engine was pointed out, together with the improvements introduced which rendered it safe and automatic.

March 14. To the Navy Yard in Charlestown, to see the powerful machinery employed in bending timber, the invention of Mr. Griffith, together with the travelling cranes, hydraulic presses, the Corliss steam engine, boilers, feed water heating apparatus, etc.

March 30. To the works of the Iron and Steel Company at Nashua, N. H. Here the students had an opportunity of seeing a Semen's gas furnace, the Martin process for making steel, Armstrong's hydraulic cranes and accumulators for handling the ladles and ingots, the process of forging and finishing steel, and the rolling of large steel tires, requiring the use of heavy steam and hydraulic machinery. They also visited the Nashua Cotton Mills, where they saw a Boyden turbine of enormous power; also the works of the Nashua Lock Company.

April 27. To the Atlantic Works, in East Boston, to observe the practical working of Mr. Ellis's Binary Vapor Engine for economizing the heat of exhaust steam by using it to vaporize sulphide of carbon. The ingenious air condenser was noticed, also the precautions to prevent the leakage of the volatile fluid. The analogy and the difference between Mr. Ellis's engine and that of M. DuTrembley was pointed out. Visits were made to the pattern shop, forge, and machine shop.

In concluding this portion of the report the Professor in charge desires to express his obligations to the Superintendent of the Boston, Lowell and Nashua Railway, and to the Super-

intendents of the various establishments visited, for courtesies extended.

ADDITIONAL MODELS.

The following additional models have been received during the past year:—

A beautiful model of a warped helicoid with its tangent hyperbolic paraboloid.

A set of models illustrating the principles of perspective.

A set of models of right and oblique bridges, with their approaches and other accessory works.

Model of a furnace and fire grate.

Model of a French boiler.

Model of an endless screw motion.

Model of a face wheel and lantern gearing.

A highly finished model of the compound engines of the screw steamship Hecla, of the Cunard Steamship Line, presented by David MacIver, Esq., of Liverpool, England.

The following models were omitted in the report for last year: —

A new form of coupling, presented by Mr. S. P. Ruggles.

A new form of pulley, presented by Mr. N. M. Lowe, and called by him a universal pulley.

A silent feed motion used in sewing machines, presented by Mr. Charles L. Spencer.

A model of the metallic packing of a steam piston, presented by Mr. Horace McMurtrie.

Models of the peculiar mechanism of stem-winding watches, presented by Mr. J. H. Gerry.

Models of eccentric gearing, presented by Mr. S. P. Ruggles.

In conclusion, attention is called to the three-fold use of the models; first, in the drawing rooms as objects from which sketches and finished drawings are made; second, in the lecture

rooms, to illustrate the principles of machinery, and to exhibit to the eye what would otherwise require long and tedious explanations; and third, in the practical exercises in construction and design, which would be difficult, if not impossible, without them.

All of which is respectfully submitted,

WM. WATSON,
Professor of Mechanical Engineering,
Mass. Institute of Technology.

REPORT ON THE INSTRUCTION IN THE DEPARTMENT OF ENGLISH.

President J. D. Runkle, Sir: —

I beg leave to present the following Report of my doings in the department of English and History during the past school year.

The question of the best method of adjusting my instruction to the real wants of the students of the Institute, has been from the outset a very perplexing one. The imperfect preparation for the scientific studies of the course which the students bring with them lays a heavy pressure upon them in that direction; and, on the other hand, the deficiencies of too many of them in English studies require an attention to rudimentary drill, especially in Composition, which should properly have been completed before admission. A gradual but steady rise in the standard of qualifications for admission to our school, to correspond with the improvements which are making in the English and Scientific instruction given in our High Schools, will eventually remedy much of this difficulty. I have to report that I have been successful in securing a regular attendance and an interested attention to my lectures. I have nothing but praise for the conduct of the students, and am confident that good results have been attained beyond what can be exhibited by a formal

examination. Students just emancipated from the restraints of school, and just passing from boyhood into young manhood are in a peculiarly receptive condition of mind in regard to the moral, political, social and æsthetic questions which form the real subjects of instruction in History and Literature. They are beginning to think for themselves, and are looking forward to a new future, where they will have to act for themselves. It is a period when judicious oral instruction can be made of more value than either before or afterwards. Lecturing therefore forms a very legitimate method of instruction, and, where the student's brain is constantly taxed by a very large amount of hard mathematical and scientific study, so that the mental discipline must under any circumstances come mainly from the scientific side, lecturing must continue to hold an important place in the literary and historical departments; and, it is very observable that the mental training obtained through the instrumentality of the severe discipline of the former class of studies perceptibly increases the intelligent interest of the students in the latter.

But lectures, to be of any value, must be supplemented by some literary as well as scientific work on the part of the students; and as it would be wholly impossible for one teacher to give elaborate and distinct courses of instruction in Rhetoric, Logic and Criticism, and also in political and literary History, my aim has been to comprise as many different elements as I could in one or two courses, and to connect with them as much practice in writing as time permitted. The students of the classes of the first and second years have taken brief notes of lectures, and written them out in manuscript books, which have been regularly examined by my assistant, and all elementary errors in spelling, punctuation and style corrected. Elementary deficiencies are very general. I have taken the ground that while the Institute of Technology does not offer itself as a teacher of writing, spelling, punctuation and the rudiments of the art of composition, it will give all the incidental help it can to its students for the making up of such deficiencies in their

school education, but should refuse to give a degree or diploma to any student who, by the end of the four years, has not acquired, directly or indirectly, a satisfactory proficiency in them

I think that by devoting a larger share of time to drill in composition during the first year, that object can be satisfactorily attained. After the first year, I am anxious to carry out more fully the system of requiring a certain amount of prescribed collateral reading in connexion with the lectures on History and Literature, accompanied by oral or written analyses of the same, or even lectures to be given by the students themselves. In this way practice in composition may be clearly combined with the oral instruction, and the general interest will be increased through the students themselves taking a more active share in the work. But for the proper carrying out of such a plan, I greatly need better library accommodations, and a better supply of carefully selected books; not a miscellaneous collection on any and all topics, but exactly the books that contain the collateral reading I wish to require. I consider that one of the greatest services I can do my pupils is to teach them how to use books. Their knowledge of the contents of English Literature and of the character and relative value even of modern writers, as tested by examination, is surprisingly small.

My course of instruction for the past year has been as follows: —To the first year's class I have lectured once a week on the writers of the last century, devoting a good deal of time to elementary ideas on the study of Literature in general. Notes of these lessons have been written out by the class. The other weekly exercise has been devoted partly to Composition, partly to lessons on Language and General Grammar, with special reference to the history of the English language. A portion of this last instruction could be given hereafter to better advantage by the Professor of Modern Languages, in connexion with the instruction in German and French, if a professor should be appointed who has a competent knowledge of the science of Comparative Philology, leaving me more time for much-needed work in the details of practical composition.

With the second my lessons have been mainly confined to the history and literature of the Eighteenth century, with special reference to English History and the events of our Revolution. The class have taken notes. They have shown much interest, especially in the American portion of these lessons, and might have done a good deal of collateral reading without detriment to their severer studies, if books on American history had been immediately at hand in the reading-room.

To the third year's class I have given a detailed series of lessons on the U. S. Constitution, along with as much instruction on English constitutional history and the general principles of constitutional law as time and my own reading permitted. These have occupied one of the two weekly hours. The other has been devoted to the oral translation, with a running commentary, of Guizot's "Civilization en Europe," the students having the French text open before them. Their knowledge of French has been thereby somewhat improved, and it has been the best means I could devise of giving the class a general view of the outlines of modern history. These lessons can be made much more valuable by going more slowly over the book and requiring some collateral reading, and occasional oral or written translations from the students.

With the fourth year's class my attention has been mainly devoted to Political Economy and the Commercial and Economical aspects of History. Adopting the smallest and least controversial manual that I could find, I have made it the text for a series of readings and oral lessons, designed mainly to interest the class in the investigation of the various politico-economical subjects, which have so close a connexion with their professions and future occupations in life. No subjects belonging to the English department are more important, or have proved more interesting to the students than these; but in the more technical parts of Political Economy, the subjects of Currency, Banking, &c., I have to lament my own lack of practical knowledge; and I would respectfully suggest that a brief course of non-contro-

versial lectures on these topics, explanatory of the ordinary course of business, and given by a practical business man, would be very useful.

The only assistance of this kind which I have received this year has been a short, but excellent course of lectures, given to the classes of the third and fourth years together, by Hon. Emory Washburn, Bussey Professor of Law in the Harvard Law School, in which the students were much interested. I feel personally under great obligations to Ex-Gov. Washburn, for this assistance, given, at the cost to himself of a good deal of time and trouble; and thanks are due to him for the interest he has thus again practically shown in our institution.

In this connexion I will also mention our obligations to Hon. Charles Sumner for repeated gifts of valuable public documents.

As the result of the enlargement and reconstruction of the course on Science and Literature, I have had, during the second term a small extra class in English studies. From want of time, owing to the absence through illness of Prof. Howison, I have not been able to do anything very systematic with them. They adopted my proposal to study, as far as time allowed, in connexion with our two weekly meetings, the actual present condition, political, social and economical, of some of the leading nations of the world, as given in the most recent authorities; as E. G. Martin's Statesman's Year-Book, the writings and speeches of Grant Duff, the leading periodicals, &c. The experiment was sufficient to show how valuable and interesting such instruction might be made to young men who are looking forward to the active career of business men, manufacturers or merchants, and I trust that as our institution develops, more resources may be put at the command of the English department for perfecting it.

After this detail of my labours I hardly need say that they have been too varied and multifarious to allow of their being performed with proper thoroughness. I look forward with the greatest satisfaction to the prospect of sharing the work of this department with another teacher. With the aid of a Professor

of Modern Languages, if we shall be so fortunate as to obtain one, I shall hope to be able next year to confine myself to a narrower circle, and to be able to undertake with the students in Science and Literature more careful and detailed extra instruction in History and English Literature.

All which is respectfully submitted.

W. P. ATKINSON.

May 19, 1872.

REPORT OF THE DEPARTMENT OF PHYSICS.

To the President of the Institute:—

A somewhat detailed account of the course of instruction in the Physical Laboratory has been given in previous annual reports, and it remains substantially unchanged for students of the Third Year, except by the introduction of many additional experiments. The present Report will therefore be confined to a description of the extension recently made by introducing the study of Physics into the Fourth Year. In the earlier part of the laboratory course a full description is given of each experiment, and the apparatus necessary for performing it is put in perfect order, so that the student can at once proceed. This, however, is very different from cases arising in actual practice. The engineer or chemist who wishes to undertake any original investigations must generally devise his own apparatus, make it, or at least superintend its construction, perform the necessary experiments, and finally, if the results are of value, prepare a report of them for publication. The subject is presented to the students of the Fourth Year in precisely this form. A problem in practical physics is suggested to them which they are expected to work out experimentally, and report the results. As examples the following extracts from a portion of these reports are appended, retaining as far as possible the student's own words. The illustrations are necessarily omitted, also the curves exhibit-

ing the results, and in most cases the tables are very much abridged. The actual amount of work done is therefore much greater than would appear from the perusal of the following pages. As this course has been on trial only during the past four months, great improvements are to be expected when experience has shown the kinds of experiments that can be most profitably performed by the student, but we believe that enough has already been done to show that results may be obtained, which shall be of great use to the student as a method of training, and at the same time possess considerable scientific value.

MECHANICS OF SOLIDS.

A number of pine rods as nearly alike as possible were provided and used by the students as units with which to form a variety of trusses. The following will serve as an example:

Report upon Experiments on a Queen-Post Truss and its component parts, by Messrs. C. S. Ward and B. E. Brewster.

Several series of experiments were made upon a number of beams supported at both ends, distance between supports being 66″. Weight applied in the centre, 6 lbs.

The deflection was measured by means of a millimetre scale pasted upon a strip of wood, and suspended in the middle of the beam. The beams used were 6′ long, and $\frac{1}{2}$″ square.

(In the original report a table is here inserted, showing measurements of scale-readings before and after the weight was applied, the deflection and permanent set. Five beams were used, and the measures repeated after turning them over. Deflections in cm. were as follows:— 7.85, 7.95, 9.15, 9.50, 7.95, 8.05, 10.30, 10.65, 7.45, 7.80).

Average Deflection, 8.86 cm. Average permanent set, .5 cm.

Another beam, No. 6, was similarly tested on its 4 sides to compare the relative strength. Deflections, 7.80, 8.00, 7.90,

7.85. Beam No. 6 was loaded as before with a wt. of 6 lbs. and readings taken at intervals of $\frac{1}{2}$ minute until deflection became constant. Results 12.90, 12.95, 13.05, 13.10, 13.15, 13.15, 13.15. The first reading was at the end of one minute. Curve No. 2, represents this increase of deflection.

Beam No. 5 was used for determining the deflection under a varying weight. Deflections from 0 to 8 lbs., 5.00, 6.30, 7.55, 8.85, 10.15, 11.50, 12.75, 14.05, 15.75. By examination we see that the changes in deflection were very constant, with the exception of the last, and in accordance with the law that the deflection is proportional to the weight. Curve No. 3 shows this result. Next, experiments were made to get the form of the deflected beam. For this purpose a constant weight of 8 pounds was applied in the middle, and a series of readings with and without the load was made at points 3″ apart. Length of beam as before, 66″. Deflections, 9.9, 9.85, 9.60, 9.80, 8.30, 7.35, 6.30, 5.10, 4.00, 2.65, 1.15. The deflections are shown in Curve No. 4.

A weight of 6 lbs. was then applied to the beam at different points taken at intervals of 3″ from 33″ to 15″, in order to determine the relative deflections, which were 12.75, 12.60, 12.30, 11.70, 10.80, 9.80, 8.70.

The breaking strength of the beams was then tested. Distance between knife-edges, 5′, weight applied in the centre. The tension on the beam at the moment of rupture was noted by means of a spring balance ; accuracy limited to $\frac{1}{4}$ of a pound. Breaking weight of beams Nos. 7 and 8, $17\frac{3}{4}$ and $18\frac{1}{2}$ lbs. respectively.

From beams similar to those already experimented upon, a queen-post truss was built of the dimensions shown in the figure. Length of truss, 60″. Height, 10″. Distance apart of queen-posts, 20″. Distance apart of two trusses forming sides of bridge, 12″. Beams bolted together with iron bolts $1\frac{3}{4}$″ long, $\frac{1}{7}$″ in diameter.

The combined trusses were first subjected to a load of 100 lbs. applied midway between the trusses, and distributed uniformly throughout the length. Readings were taken at 7 points of the roadway at distances from one end of 3, 10, 20, 30, 40, 50, 57 inches respectively, that is one three inches from each end, one ten inches from each end, one at bottom of each queen-post and one at centre. Deflections, .20, .50, .50, .60, .60, .35, .20. The deflection was greater at one end of the beam than at the other, because there was a split in it. Curve No. 6 represents the results.

A weight of 70 lbs. was then applied in the middle of the truss with the following results, the points being at same distances as before. Deflections, .18, .04, .41, .88, .53, .02, .18. Curve No. 7 was constructed from these data. By inspection of this curve it will be seen that the beam actually rose a little between the bottom of the queen-posts and the ends of the main beams, owing to the whole thrust acting in the centre.

Measurement of the strain on the queen-post. The post was removed and a spring-balance substituted in its stead, the distance being kept constant with each succeeding additional weight by means of a rod with adjustable nut. Applying at the centre eight 10 lb. weights in succession the observed strains were as follows: — 2, $5\frac{1}{2}$, 8, 10, 12, $14\frac{1}{4}$, $16\frac{1}{2}$, $17\frac{3}{4}$. In curve No. 8, horizontal distances represent weights, and vertical distances strains, on the post.

Strain on Struts. Found by replacing one of them by a spring balance in a similar manner to that described in the preceding experiment. With weights of 0, 10, 20 and 30 lbs., the strains were $4\frac{1}{2}$, $10\frac{3}{4}$, $16\frac{1}{2}$, and $22\frac{1}{2}$ lbs. respectively. Curve No. 9 was constructed in a similar manner to No. 8.

Similar experiments were made by Messrs. Dodge and Sparrow, preparatory to building a model of a Howe truss.

They first tried different methods of connecting two beams

end to end, and measured the force required to separate them. To test the method of computing the strains on any part of a truss, a beam was fastened at one end to an upright, the other end being held by an oblique tie-rod. The strain on each of these was measured as before by inserting a spring balance and compensating screw. The strain was thus measured for each pound weight added to the end, up to 15 pounds, and compared with the theoretical strain. The deviations due to friction, error in the balance, &c., were very small.

They then constructed a complete Howe truss of length 64″, width 12″, and height 8″. The ties were made of brass rods, on which they cut screw threads and made nuts to fit them. The finished bridge was tested by applying a load at the centre, ten lbs. being added at time, with results as follows: —

Load,	10	20	30	40	50	60	70	80	90	100.
Flexure,	.50	.75	1.25	1.75	2.25	2.75	2.85	3.45	3.75	4.25.

It will be seen that the deflection was only about one-sixth of an inch for a load of one hundred pounds.

Comparing this result with the flexure of a single beam, we see that the stiffness of the latter is only about one three-hundredth of that of the truss, and the student by placing his hand first on one and then on the other, has a far more convincing proof of the value of the truss system, then he could attain by any amount of mere theoretical study. A very complete model of a suspension bridge was made by Messrs. Stafford and Shepard, using common iron chain for suspension. Its span was 8′, and deflection 8″. The roadway was hung by 15 suspension-rods on each side, and the change in position of each was measured with the load applied at a single point, and also when uniformly distributed.

Measurement of the Angular Deflection of Beams fixed at one end.
By Mr. C. F. Allen.

The apparatus for this experiment when ready for use was as follows: — I. The beam itself, whose section was $\frac{1}{2}$ inch square, and length about 30 inches, carried a scale extending over 20 inches of its length. The beam was firmly clamped at one end between two other beams of sufficient stiffness to prevent any bending action from being transmitted beyond the outer point of support, and at its end a wire was fastened from which weights could be suspended. II. A mirror of plate glass mounted so that it could easily be attached to the beam at any point. III. A telescope with cross-hairs, mounted upon a wooden stand placed 60 inches from the mirror, and carrying a vertical scale; the zero point of the scale and the line of collimation or axis of the telescope being in the same horizontal plane with each other and with some point of the mirror. IV. Weights of $\frac{1}{2}$, 1, 2, 2, 4, lbs. respectively.

Principle:—When the beam was unloaded, the 0 of the scale was reflected upon the cross-hairs of the telescope; when a weight was attached, the beam was bent, the plane of the mirror was deflected through the same angle as that point of the beam to which it was attached, and the line of collimation of the telescope moved through double this angle; so that the deflection shown on the scale (in inches) divided by 60 gives the tangent of twice the angle of deflection of the beam; therefore the angle is easily determined by observing the deflection on the scale.

The experiment was divided into three parts;

1. The length of beam remaining constant with the mirror placed at the outer end of the beam, the weights were varied.

2. The length of beam and weight remaining constant, the position of the mirror was varied.

3. The weight being constant and the mirror placed at the outer end of the beam, the length of the latter was varied.

1. The length of the beam in this case was 20 inches and the weights $\frac{1}{2}$, 1, $1\frac{1}{2}$ lbs., etc., adding $\frac{1}{2}$ lb. each time up to $5\frac{1}{2}$ lbs.: a second series of observations was then obtained by removing $\frac{1}{2}$ lb. each time: this was repeated three times making in all a series of six observations, with the following results:

Weights.	*Mean Scale Deflection.*	*True Angles.*
.5	1.16	0° 35′
1	2.15	1° 05′
1.5	3.21	1° 38′
2	4.12	2° 09′
2.33	5.45	2° 45′
3	6.59	3° 24′
3.5	7.92	3° 47′
4	9.23	4° 22′
4.5	10.35	4° 54′
5	11.54	5° 27′
5.5	12.45	5° 57′

2. The length of beam in this case was as before, 20 inches, the weight 5 lbs., and the mirror was placed at the outer end. Moving the mirror successively through intervals of 2 inches, the scale was read each time when the beam was not weighted, and again when the weight was added, the difference being taken as the scale deflection.

The results are shown below:—

Distances from Fixed End.	*Scale Defl.*	*True Angles.*
20	11.41	5° 23′
18	11.39	5° 23′
16	11.19	5° 24′
14	10.62	5° 01′
12	9.59	4° 42′
10	8.56	4° 15′
8	7.93	3° 46′
6	6.71	3° 11′
4	5.14	2° 27′
2	3.49	1° 40′

3. The weight was 5 lbs., the mirror was placed at the outer end of the beam, and the length of beam was varied two inches at a time, with the following results: —

Length of Beam.	*Scale Defl.*	*True Angles.*
20	11.42	5° 23′
18	9.56	4° 32′
16	7.56	3° 35′
14	5.93	2° 49′
12	4.56	2° 10′
10	3.17	1° 31′
8	2.07	0° 59′
6	1.32	0° 38′
4	0.65	0° 19′
2	0.24	0° 57′

Accompanying this are sheets showing the curves according to Experiment and Theory for each of the above cases.

Apparatus for ruling lines with a Diamond. By Mr. C. F. Allen.

This consists merely of a beam, with a slot at one end to receive the handle of a common glazier's diamond, and revolving upon an axis at right angles to its length, this axis being supported at its ends on upright posts. The pressure under which the diamond marks is thus kept sensibly constant and may be regulated by weights hung on the beam. The line is ruled by drawing the glass under the diamond.

This apparatus gives excellent results, some lines being so fine as to be difficult of perception under the $\frac{1}{8}$ inch objective of a microscope.

HYDRAULICS.

Coefficients of Efflux. By Messrs. W. B. Dodge and W. E. Sparrow.

The object of this experiment was to find the coefficients of efflux for different orifices and under various heads.

In this case there were two vessels, one for the water to flow from, and the other for receiving it. Each one contained a hook gauge by which heights could be measured very accurately. The gauge consisted of a wire with a pointed hook at its lower end; the other end moving vertically over a scale graduated to inches and decimals of an inch.

We fill the vessel until the water is level with the lower edge of the orifice, and take a reading by means of the gauge. The water is then allowed to run into the vessel and reach such a height that it just begins to flow away by the waste pipe. From the reading taken at this point, subtract the former one together with the distance of the centre of gravity of the orifice from its lower edge, and we thus have the true head.

In order that we may know the amount of water that flows into the second vessel, it must be carefully calibrated. This was done by pouring in one tenth of a cubic foot of water, taking a reading, and so continuing until the vessel was full.

Having described the apparatus in a general way we now proceed to perform an experiment. We first insert an orifice, say a circular one. The water is allowed to flow through it running to waste through a large rubber hose till the supply of water is so regulated that the head becomes constant. Then determine its magnitude in the manner described above. At a given signal the hose is removed and the water allowed to flow into the second vessel; at the end of a given interval of time the rubber hose is replaced and the water again runs to waste. The difference between the readings of the gauge in the lower vessel before and after the experiment gives the amount of water that will flow through the orifice, with the given head, during the given interval of time.

For heads which are at least four times the height of the orifice, theory gives for the discharge, the area of the orifice multiplied by the velocity due to the height of the water above the centre of gravity of the orifice. By dividing the actual by the theoretical discharge we obtain the coefficient of efflux.

Different orifices were used under various heads, and the results are placed in tabular form below:—

Shape of Orifice.	Dimensions.	Area.	Head.	Time.	Discharge		Coefficient of Efflux.
					Actual	Theoretical	
Square.	.5″ × .5″	.25″	14.51	2	.460	.724	.63
			14.64	2	.468	.768	.61
			14.62	2	.464	.767	.61
Rectangle.	height .25″ depth 1.00″	.25″	10.10	2	.516	.638	.81
			10.10	2	.518	.638	.81
			10.12	2	.541	.638	.85
Rectaugle.	height = 1.00″ depth = .25″	.25″	12.64	1	.575	.713	.81
			12.78	2	.570	.717	.79
			12.64	1	.575	.713	.81
Triangle.	base .55″ height .546″	.15″	14.85	3	.304	.465	.65
			14.97	3	.307	.466	.66
			14.83	4	.304	.464	.66
Circle.	diam. = .5″	.196″	14.53	2	.465	.613	.76*
			14.35	2	.382	.594	.65

The friction of water in pipes was also measured by several students, using a horizontal brass pipe to convey the water, with vertical glass tubes having scales attached to show the pressure at different points. This gave the friction under a velocity which was found by measuring the amount of water escaping per minute.

Buoyant effect of a column of heated air from a Bunser burner.
By Mr. C. K. Wead.

A metal plate 283 mm. in diameter was placed over the flame and hung to one arm of a balance, and the force required to counterpoise it measured by double weighing. With no flame the force was 428.65 grs., with full flame 1 metre below, 431.2, at distance .8 m. 431.26, at .6 m. 431.

Using the formula for winds, (Silliman) velocity in miles per hour $= 14.25 \sqrt{\text{pressure in lbs. per sq. ft.}}$

Hence velocity=1.53 miles per hour=2.24 ft. per second.

* Erroneous.

2d Experiment. A [illegible] was substituted for the plate.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.6	2.73	2.84	2.81	2.[illegible]
0.8	2.67	2.88	2.82	2.[illegible]
1.0	2.88	2.78	2.88	2.[illegible]
1.2	2.91	2.88	2.78	2.[illegible]
1.4	2.86	2.84	2.81	2.[illegible]
1.6	2.67	2.87	2.[illegible]	
1.8	2.83	2.84		
2.0	2.[illegible]	2.[illegible]		

The currents were easily diverted from a vertical direction, and so probably the maximum velocity is more correct than the mean.

OPTICS.

Law of Lenses. By Mr. C. A. Wood.

The focal length of the plano-convex lens A on the stand was found to be 23.03" ± .03. In this experiment the formula $\frac{1}{F}=\frac{1}{f}+\frac{1}{f'}$ was used, and f + f' taken equal to whole distance between conjugate foci, *i.e.*, no correction was made for thickness. The same lens was remeasured and focus computed allowing for thickness, that is, f + f' + t — whole distance between conjugate foci; the formula used was

$$\frac{1}{F}=\frac{1}{f}+\frac{1}{f'}-\frac{t}{n}\left(\frac{1}{r}+\frac{1}{r'}\right)^2$$

t_A=.25", r_A (by spherometer) = 12.64", n = 1.51. From this observation F_A' = 22.62 ; .02 taking in all the terms.

F_A' = 23.11 ; .01 omitting the third term.

In this case it makes a difference of .51" in the final result whether the focus of reflected rays is measured from the first or second surface of the lens, and if taken from the second neglects the correction for thickness. [illegible] were made on a second lens, and on two occasions with the same surface [illegible].

The focus of a Tolles ¼" objective, 2d quality, was measured by the method of Prof. Cross (Journ. Frank. Inst., June, 1870). A spider line micrometer and $\frac{1}{1000}$" stage, were used and both measured in turns of the same part of the screw of the dividing engine; there is therefore no absolute measure entering into the formula for focal length, except l the distance between object and image, which was taken with a steel mm. scale. The foci of the three lenses A, B and C, of the triplet, were measured singly and in combination with the following results:

Lenses.	Focus.	l.	n.
$A\,B\,C$	.2447	256	39.11
$A\,B\,C$	.2555	216	31.26(?)
$B\,C$	.4454	258	20.766
A	.2081	260	31.186
B	.3076	258.5	16.764
C	1.439	287	5.571

The relative distances of the lenses were then measured and gave for thickness of A, .066, of B, .101, of C, .124, space between A and B .080, between B and C .007; length of whole combination = .288. Computing focus of BC, we get .407 or .411, according as we do or do not consider the small uncertain distance between them. The formula is based on the supposition that the rays are parallel, which may account for the slight difference.

Photometric Experiments. By Mr. C. K. Wead.

The following observations were made with a photometer in which two images of a single flame are compared, thus eliminating all errors from the fluctuations of the light.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Consumption.	*Observed C. P.*	*Corrected for candle.*	*Probable Error.*
5.974	24.03	25.00	.24
4.848	15.12	16.50	.13
4.818	15.20	16.09	.11
4.965	15.60	16.25	.12
3.828	12.86	10.45?	.12
2.568	8.46	8.29	.07
1.488	.222	.255	.005
.420			

The first column gives the consumption of gas; the second the observed ratio of the two lights, being the mean of from four to seven observations; the third the candle power corrected for amount of wax burnt, and the fourth the probable error. In the last case the light was too feeble to be measured, probably less than .001 of a candle power.

Experiments like the above by members of the 3rd Year's Class gave the following results.

Messrs. Shailer & Harris.			*Messrs. Blaisdell & Jewett.*		
Consumption.	*Observed C. P.*	*Corrected C. P.*	*Consumption.*	*Observed C. P.*	*Corrected C. P.*
6.12	18.35	19.27	6.45	19.7	21.67
4.92	18.9	19.37	5.98	17.5	18.37
3.60	11.56	12.14	5.22	15.7	15.31
2.28	2.91	3.28	5.38	17.2	15.90
1.52	.37	.35	4.84	12.4	13.02
1.44	.027	.029	4.35	14.1	11.47
.35	.00	.00	4.55	12.75	14.80
			4.09	12.79	12.79
			3.69	9.71	9.22
			3.37	7.34	7.71
			3.07	6.94	6.24
			2.96	3.84	4.03
			2.77	3.68	3.68
			2.46	2.17	2.28
			2.26	1.32	1.45
			2.04	.84	1.00

For the practical application of these observations, see papers by Profs. Silliman and Stimpson on Farmer's Law, in the Amer. Journ. Sci., 1870.

To Find the Refractive Formula (that of Cauchy) for any Substance. By Mr. F. W. Very.

The substance must be in the form of a triangular prism which is obtained in the case of a liquid by pouring it into a glass vessel of this shape. In the case under consideration, the substance was a piece of very dense and highly refractive glass, made into a prism having an angle of about 60°.

The instrument used was an optical circle, carrying two telecopes, one stationary for the purpose of furnishing a parallel beam of light, the other moving around the axis of the graduated circle, and having two verniers by which the angle may be read. The prism being placed at the centre of the circle, the light is refracted and dispersed, and the spectrum is observed through the second telescope.

The operation is as follows. The refractive index of the prism is taken for several of the most prominent lines in the spectrum, whose wave-lengths are known. This is accomplished by measuring the angle of minimum deviation D for each line and the refracting angle A of the prism, when the index n may be calculated by the formula,

$$n = \frac{\sin \frac{A+D}{2}}{\sin \frac{A}{2}}$$

It is necessary to find the index for at least three lines, but to insure greater accuracy a number of others were taken. The results were compared by means of the graphical method, and a slight correction was made upon three measurements at some distance from each other in the series.

These three values of n were then substituted in the formula,

$$n = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \text{etc.},$$

in which all the terms in the second member after the first three may be neglected. By elimination, the values of the con-

stants A, B and C for the substance under examination were found. In this case, they were as follows: $A = 1.683473$, $B = 96.30$, $C = 446.67$.

Having obtained the formula of the prism, it may be used to find the wave length of any line whose index of refraction has been measured.

To measure A, the refracting angle of the prism, this angle is placed facing the collimator so that the parallel rays coming from the latter shall be reflected from both faces of the prism as shown in the figure. The angle between the directions of the reflected rays $= 2A$ is measured. These measurements gave $A = 60° 1' 7''$, $60° 1' 0''$, $60° 1' 41''$, or the mean $60° 1' 20''$. The observing telescope was first focussed on an object about 80 ft. off, the focus of the collimator was then brought into agreement, and neither was changed during the measurement.

The prism being then placed in position and set at the minimum of deviation for each line in turn, the deviation was measured.

Line.	*Deviation.*	*n.*	$\lambda \times 10^7$	$\frac{1}{\lambda^2} \times 10^{-10}$
Na	58° 6′ 45″	1.71499		
Li α	57° 13′ 15″	1.70692		
B	57° 5′ 37″	1.70576	.000 6867	212.06
C	57° 21′ 45″	1.70813	6562	232.24
a	57° 39′ 0″	1.71081	6277	253.80
D	58° 6′ 37″	1.71495	5892	288.05
E	59° 7′ 52″	1.72404	5269	360.20
b	59° 17′ 52″	1.72551	5183	372.25
F	60° 4′ 7″	1.73226	4860	423.38
Ti	60° 38′ 0″	1.73716	4665	459.52
Fe	61° 38′ 0″	1.74573	4383	520.54
H	61° 49′ 7″	1.74730	4340	530.91
Fe	61° 53′ 22″	1.74790	4325	535.83
G	61° 56′ 45″	1.74838	4307	539.08
	61° 59′ 37″	1.74876	4300	540.83
Fe	62° 11′ 37″	1.75011	4271	548.20
Cu	62° 20′ 22″	1.75170	4226	559.94

Micro-photography. *By Mr. C. S. Minot.*

During the course of instruction in photography by Mr. Whipple, it occurred to me that some experiments in micro-photography would be interesting. I accordingly arranged an apparatus by which the tube and lenses of a microscope could be substituted for those of a photographic camera. A box was taken, the back was knocked out and a hole a little larger than the diameter of the tube of the microscope was bored in the front. This hole was lined with felt to make it light-tight. On the back was fitted a slide which carried the ground glass plate on which the image was focussed, and the plate-holder.

The first experiment was with an $1\frac{1}{2}$ inch objective of Smith and Beck, and a Tolles B eye-piece. The size of the image photographed was $2\frac{1}{4}$ inches. The exposure lasted 4 seconds, direct sunlight reflected from a plane mirror being used. See No. 1. Similarly a fly's tongue, No. 2, and a section of Echinus spine, mounted in balsam, No. 3, were photographed.

I next attempted to take *Arachnoidiscus Ehrenbergii* Bailey, using a Tolles 1st quality $\frac{1}{4}$ with a B eye-piece. After several failures, caused by the shaking of the table during the exposure of the plate, I was successful (see No. 4). The exposure was four minutes and forty seconds.

Other negatives were taken with a B eye-piece and various objectives (see Nos. 5, 6, and 7).

I made one trial with an extension camera in order to obtain greater enlargement. With this I took *Arachnoidiscus Ehrenbergii*, using no eye-piece. The focussing was not perfect, however, and at the intersections of the lines, a beaded appearance is quite sharp and distinct, and suggests a doubt as to the value of Dr. Pigott's views as to the structure of podura scales as seen by his so-called "wonderful" aplanatic searcher. This photograph is No. 8.

I had proposed to use monochromatic light but had no time. My intention was to use light passed through an ammoniacal

solution of cupric sulphate. The object in using blue light would be to avoid the difficulty of the objectives not being ground to the chemical focus.

The cost of the apparatus to take these photographs, when one is provided with a microscope and objective, and exclusive of what can easily be made, is only about $10 for what is needed to take negatives, and $5 or $6 more for the printing.

Saccharimetry. By Mr. F. A. Emmerton.

The delicacy of the instrument to be used was first tested by adjusting the eye-piece, so that the sensitive violet tint was obtained, and then taking four successive readings, at the point when the color was the same in both sides, using water only in the tube.

These readings were as follows:

—.9; —.9; —9; —5;

thus showing that the instrument is quite sensitive.

The 0 point was evidently .9 of a division too far to the left, consequently it was adjusted, by use of the screw attached to one of the prisms, so that the point when the colors on each side of the field were the same, was always 0.

A sugar solution was prepared of presumably pure sugar so that it contained 16.471 grs. to the 100 c.c.

It was allowed to stand in the chemical laboratory five or six days before use, corked up in a flask. In that time it had changed by fermentation, as is shown by the following results:

99.1; 98.8; 98.9.—Average 98.9 per cent.

If the solution had not changed the readings should have been 100.

Another standard sugar solution was used immediately after preparation and gave the following results:

100.0; 100.1; 99.8; 100.1; 100.—Average 100.00 per cent., showing the sugar to be quite pure.

The long tube belonging to the instrument and intended to

be used for solutions after inversion ought to be one tenth longer than the short tube, in order to compensate for the 10 c.c. of HCl added to every 100.00 sugar solution in the inversion.

Consequently with a normal sugar solution it ought to give readings one tenth more than the short tube. It was tested with the pure normal sugar solution with this result:

110.9; 110.9; 110.6; 110.9; 110.9 per ct.—Average 110.88.

Showing the tube to be not exactly one tenth longer than the short one.

The same solution was tried three days after in the short tube with these results:

98.6; 98.4; 98.3; 98.3; 98.7 — Average 98.46, showing how rapidly a sugar solution changes in strength even when corked up in cool weather.

In looking for statements about the relative rotating power of inverted and uninverted sugar solutions I found great discrepancy of statement, but concluded from a statement in Bolley that the amount of sugar which rotates to the right 100, rotates to the left at 35.7 at 15° C. I inverted the pure solution and got the following readings at 18° C.

—37.6; —37.3; —38.; —37.9; 37.2.—Average 37.6.

Subtracting .88 the error due to the length of the tube it gives 36.7 as the reading at 18° C. I could not find any tables giving the correction for temperature, but that correction whatever it is would bring the reading nearer still to 35.7.

A large number of electrical experiments were made by the class, including measurement of resistances, making coils, a Siemens' thermometer, magnetization by frictional electricity, and others, but they are omitted, believing that the above are sufficient to show the nature of the work done, both as regards quality and quantity.

All of which is respectfully submitted.

EDWARD C. PICKERING,

Thayer Professor of Physics.

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J. P. Bruce
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Massachusetts Institute of Technology.

PRESIDENT'S REPORT

FOR THE

GENERAL LIBRARY University of MICHIGAN

Year ending Sept. 30, 1873.

BOSTON:
PRESS OF A. A. KINGMAN,
1873.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1873.

BOSTON:
PRESS OF A. A. KINGMAN.
1873.

PRESIDENT'S REPORT.

To the Corporation of the Institute: —

This report relates to the year ending Sept. 30, 1873, to correspond with the fiscal and school years as now established.

In my last report so much space was devoted to several of the departments, that it will only be necessary in this to indicate such changes as have taken place during the year.

Department of Chemistry. Professor Crafts' statement on pages 59 and 60 indicates the spirit and aim of the instruction, and alludes to such improvements as have been made in the Quantitative Laboratory to facilitate work.

The instruction in General Chemistry and Qualitative Analysis, given to students of the first and second years, has continued under the direction of Professor Nichols, and the system and thoroughness with which it has been conducted, leave nothing to be desired but ampler space. We have but one laboratory, accommodating about fifty students at a time, in which to do this work. While these classes were small, this laboratory answered the purpose fairly well; but since they have become so large, that each must be divided into two or more sections, its use has been largely increased, and an urgent need has been felt for larger and better ventilated laboratories.

Besides, it is found impossible at all times to prevent the odors from the laboratories from permeating other parts of the building. There is also a great want of proper rooms for storing glass-ware and chemicals, and laboratories for gas analysis and the various applications of chemistry.

The importance of a new building to accommodate this important department is daily becoming more apparent, not only for its own proper development, but also for the relief it will afford to other departments, which must for some time to come be accommodated in our present building.

At the last session of the Legislature, your application for a parcel of land on the Back Bay was successful, and it is certainly to be desired that such a building as we so much need may be erected thereon during the coming year.[1]

Department of Geology and Mining Engineering. The courses of instruction in this department were fully detailed in my last report. During the year the Geology has been in the

[1] An Act in addition to An Act incorporating the Massachusetts Institute of Technology.

Be it enacted by the Senate and House of Representatives, in General Court assembled, and by the authority of the same, as follows:

SECTION 1. Perpetual right is granted to the Massachusetts Institute of Technology to hold, occupy and control free of rent or charge by the Commonwealth, for the uses and purposes of said Institute, a parcel of land situated in that part of Boston called the Back Bay, and described as follows: A lot in the form of a trapezoid lying at the intersection of Boylston street and Huntington Avenue, bounded by said street and avenue, and on the west by abutting land, as laid down on the selling plan of the Commissioners on Public Lands, and containing thirteen thousand one hundred and ninety-four square feet; said lot to be subject to the limitations and stipulations relative to lands of the Commonwealth on the south side of Boylston street, and to be reserved from sale forever.

SECTION 2. The right hereby granted to said Institute shall be held subject to the same stipulations in relation to membership, the reception of pupils, the erection of a building, and the care of the lot, as are created and established by the several acts relating to said Institute.

SECTION 3. In case said Institute appropriates said lot of land to any purpose or use foreign to its legitimate objects, then the Commonwealth, after due notice given, may enter upon said lot and take possession thereof, and the right of the said Institute to the use, occupation and control of said lot, shall thereupon cease.

SECTION 4. This act shall take effect upon its passage.

April 8, 1873.

Approved.

W. B. WASHBURN.

able hands of Professor Hunt, the value of whose instruction has been much abridged by the want of proper space for reinforcing the lectures by the corresponding laboratory work.

The department has also gained largely in the more complete equipment of the Mining and Metallurgical laboratories, which is due almost entirely to the zeal, energy, and excellent prac tical judgment of Professor Richards, to whose interesting report I respectfully ask your attention. We are indebted to Mr. Schubert for the drawings, and to another friend for the engraving of the cuts representing these Laboratories.

As part of the work of the department, I include the excursion made during the vacation just closed. At my request Professor Ordway has written a full account which I submit for your information. Excursions so systematically and ably conducted as this one, are of great advantage, not only to professors and students, but also, indirectly at least, to the industries to which they relate; and I heartily approve of Professor Ordway's suggestion, that such excursions should be annual and part of the recognized work of the school, and that some way may be found to aid those to whom the incidental expense may be burdensome.

It is only just to say that all of the excursions of past years would have been impossible had it not been for the ready and generous aid given us by railroads all over the country.

Department of Physics. Last year's report on this department related to the instruction given during the third and fourth years in the Rogers Laboratory of Physics. No important change in the method of instruction has been found necessary. The laboratory has gained somewhat in apparatus, but mainly in such things as have been designed and made in the building. You are respectfully referred to the report of Prof. Cross on the instruction in physics in the first and second years of the course. The publication of Professor Pickering's Laboratory Manual, and the printing of Professor Cross' notes, have greatly aided in the instruction.

Your thanks are due to Mr. J. C. Hoadley for a valuable collection of acoustic apparatus, a list of which you will find on pages 71 and 72. The urgent need of the department is a fund, the income of which can be used to keep the apparatus up to the latest date in all branches of the subject.

Industrial Design. In my last report I had the pleasure of announcing the intention of the Trustee of the Lowell Institute to establish in this Institute a course of instruction in Industrial Design. The vote establishing the department was passed Sept. 11, 1872, and the following circular was issued shortly after, which is inserted here as part of the history of the department.

LOWELL COURSE OF INDUSTRIAL ART.

The Trustee of the Lowell Institute having made provision for a special course of free Instruction in Practical Design for Manufactures, open to pupils of both sexes, students will be received at the beginning of the school year in October, to whom will be taught the art of making patterns for Prints, Delaines, Silks, Paper-Hangings, Carpets, Oil-Cloths, etc.

The Course will embrace: —

1. *Original Design, or Composition of Patterns:* —

This comprises the making of original sketches for patterns, in light and shade, flat or shaded tints and in outline.

In connection with this work instruction will be given in the harmony of colors and in proportion.

2. *Secondary Design, or Variation of Patterns:* —

This comprises the alteration and adapting of patterns, either as to form, color, or the number of colors employed, simplifying them or making them more elaborate, and adapting them to different fabrics.

In connection with this work the study of the recognized styles will be taken up, and attention given to the peculiar requirements of various markets.

3. *The Making of Working Drawings:* —

Under this head is comprised the working out of sketches and designs, and putting them into the form and scale required by the manufacturer. Practice will be given in the method of adjusting patterns for printed goods to the size of the blocks or rollers employed, and in drawing out the patterns for carpets and other woven fabrics upon paper whose surface is divided into small squares, each representing a "pick" or thread.

4. *Technical Manipulations:* —

This comprises instruction in the use of instruments and colors, specially adapted to pattern drawing; also exercises in enlarging, reducing and copying patterns.

The class will be arranged in four divisions, corresponding to these four kinds of work. The student, on joining the class after passing the prescribed examination, will enter the fourth division and will be advaneed to the third, and to the second, and so on to the practice of original design as rapidly as his proficiency permits. The more advanced students will have the assistance of the lower divisions in the drawing out of their designs.

Instruction will be given personally to each student over his work, with occasional general exercises.

Drawing from Memory. The designer needs to be familiar with the objects and forms in use in designing, so as to be able to reproduce without a copy the details of ornament, the appearance and texture of fabrics and of natural materials, and the forms and colors of leaves and flowers, which are the chief basis of decorative art. To this end special exercises in drawing and coloring from memory will constantly be given out.

Manufacturing Processes. A competent knowledge of the machinery and other appliances in use, and some familiarity with their working, is important to the designer. Without it his designs, however skilful, will be worthless. With a view to the acquisition of such knowledge the various processes of printing and weaving will be explained to the students, as may from time to time be needful, and excursions made to manufacturing establishments in the neighborhood where these operations may be witnessed upon a large scale.

It is intended that this course of study shall be thorough and practical, so that students may here qualify themselves to become draughtsmen or designers in manufacturing establishments, as their proficiency and capacity may determine.

The class will be provided with samples of textile fabrics, paper hangings, carpets and oil-cloths, both American and European, and with specimens of Oriental and other woven and printed fabrics selected for their artistic value and as illustrating the application of design to manufactures. To these will be added some examples of drawings made by pupils in foreign schools of design

The class will be open to pupils of both sexes and will be under the personal direction of Mr. Charles Kastner, for fourteen years designer at the Pacific Mills, formerly Director of the Atelier Lebert in Paris, and nephew and pupil of M. Jean Baptiste Lebert. *Dessinateur*, of Mulhouse in Alsace.

It will open on Monday, October 7th, and will continue daily, except Sundays and holidays, until the end of May. Hours from nine till one, and from two till five o'clock, except Saturday afternoons. Regular and

punctual attendance will be strictly required. Students will supply their own instruments and materials.

Requirements of Admission: —

Applicants for admission to the Lowell Course of Industrial Art will be required to bring specimens of their work, exhibiting a thorough acquaintance with Free-hand Drawing, and some familiarity with the use of mathematical instruments, and of the brush in laying flat and graduated tints with India-ink and with color; all of which is an indispensable preliminary to the study of designing.

Entrance examinations will be held on the 4th and 5th of October at 9 A. M., at the Massachusetts Institute of Technology, Boylston St., Boston. Applicants will bring as many samples of their work as is convenient.

For copies of this circular address

SAMUEL KNEELAND,
Secretary.

Mass. Inst. of Tech., Boylston St., Boston,
Sept. 20, 1872.

A reference to Mr. Kastner's report, on page 66, will show what has been accomplished during the year in this department. It is my pleasure, as well as duty, to testify to the zeal and faithfulness of both teacher and pupils, and to express my entire satisfaction with the results. In judging of the quality of the work, it should also be remembered how little of proper preparation most, if not all the pupils, possessed at the beginning of the year. The fact that nearly all of them have returned, is the best evidence of their interest in the work.

It is important to the highest success of this department, that the pupils should remain until they are thoroughly qualified to enter upon their profession, and to this end I earnestly recommend that a course of not less than three years be marked out, and that to those pupils who successfully accomplish it, shall be awarded a diploma by the Corporation.

It is proper in this connection to state that all the expenses of the department for the year, in the purchase of samples of textile fabrics for illustrating the instruction, have been paid out of a contribution by James L. Little & Co., of two hundred dollars, and that Mr. John A. Lowell has placed a like sum at our disposal for the coming year.

Department of Military Science and Tactics. During the year we have availed ourselves of the Act of Congress, authorizing the detail of an officer of the army to give this instruction. Lieut. Zalinski entered upon this duty only in March last, but devoted himself so zealously and efficiently to the work for the small remaining part of the session that commendable progress was made towards putting the department in a satisfactory condition. Considering all the circumstances, enough was done to satisfy all reasonable expectations for the future, and particularly to show that if the discipline of the department is properly supported, it may be made a valuable element in the *morale* of the school. Lieut. Zalinski's suggestion of the need of a proper hall for the use of the department is fully endorsed; also the use which may be made of it for systematic gymnastic exercise. The adoption of a more serviceable and tasteful uniform is earnestly recommended.

Department of Mechanical Engineering. In June last Prof. Watson resigned the professorship of Mechanical Engineering and Mr. Channing Whitaker, a graduate in this department in the class of 1869, has been chosen to fill the vacancy.

It is important that this occasion should be improved in making such changes in the methods and facilities as the experience of the past seems to indicate. To this end I have asked Prof. Whitaker to suggest such a laboratory as will best aid in the education of mechanical engineers; and particularly in the solution of those experimental problems which lie at the foundation of all safe theory or practice. The delay in the issue of this report, also enables him to briefly indicate the plan of instruction which has been entered upon. Your attention is asked to his report, with the earnest wish that you will authorize the establishment of this laboratory at as early a day as possible.

Department of Architecture. Although this department was among the first established in the Institute, and was classed

with the engineering departments in the applications of the higher mathematics to Construction, it was hardly to be expected that it would at once take rank with these in the public demand and appreciation. In the first place, there were in this country neither written nor traditional precedents to serve as guides in the instruction, nor were there any suitable collections for illustration. On this account, Prof. Ware's first duty was to spend the better part of two years abroad, in examining the systems of architectural instruction, and in making the nucleus of the collections which have since served so efficiently in stimulating and promoting the work of the department. At first the department seemed to attract only those students who had, or fancied they had, some taste for art, and judged this field the one most likely to gratify the taste, and at the same time yield a reasonable prospect of support. But these students were seldom prepared by early and suitable mathematical training to take the engineering side of the course. They remained a longer or shorter time, pursuing such portions of the course as they were qualified to take, gaining more or less, in proportion to time and effort expended, but failing to reap the full benefit of the course in any particular or important sense.

We are happy to say that this early and not entirely satisfactory phase of the department, is gradually, but surely, passing away. Regular students of thorough preparation and recognized ability, are beginning to enroll themselves, and the class of 1873 is the first to represent the department among its graduates.

Each year is adding something to the appliances, but more in experience, and in improving the details of the instruction. The selection of concrete examples of immediate interest, which have not only stimulated the invention, but the industry, of the pupils, has been a marked feature of the past year.

Department of Descriptive Geometry, Stereotomy and Drawing. The subjects embraced in this department, although clearly allied, were formerly distributed, and the instruction lacked unity, and the proper coördination.

Professor Warren's report shows the order in which the several subjects are now given, but further experience is necessary to show whether the amount of graphical work required may not be somewhat diminished without serious detriment to the course. This will certainly be possible when the elements of mechanical and free-hand drawing can be required for admission, a time not far distant, so far as the State of Massachusetts is concerned.

Five small rooms have been put upon the drawing-room floor, which are used as offices for those Instructors who are mainly employed in this and the mathematical departments, to make them more accessible to those students who wish special assistance, and to aid in maintaining proper order.

Department of Civil and Topographical Engineering. The instruction in this department continues to maintain the same high character which has distinguished it from the first. Rankine's Civil Engineering is used as the basis of the theoretical instruction, and the corresponding field work is all that could be desired, both in method and thoroughness. A few large and somewhat expensive instruments are still needed, and also a few additional models of American bridges. These bridge models I hope we shall soon be able to make in our own building under the direction of the department. Last year's report was issued too early to include more than a reference to the excursion of 1872, under the direction of Professor Henck, whose brief report is included among those of the present year.

Departments of English and History, and of Logic and the Philosophy of Science. The reports of these two departments are so full, both as to the ground gone over and the methods of instruction, as to require no further remark on these points. There is, however, an important relation which these departments bear to the work of the school to which reference should here be made.

It is becoming more evident as time passes, and the profes-

sional work of the higher years is broadened and intensified by increased laboratory facilities, and by more special attention to the practical applications, that these departments can hope to do but little, if any more, than hold their present ground in the professional courses. All we can do for these courses is, by gradually raising the standard of admission, to gain more time for these subjects in the earlier years.

But there is another work of growing importance which these departments, with others, are called upon to perform in the school, and that is the work of a general as distinguished from a technical or professional education. The germ of such an education now exists in our science and literature course, and this course is gradually assuming a more marked character; but only in this, that having a less definite and specific aim than the professional courses, the ends can be accomplished by a more diversified range of subjects. Instead, therefore, of but one general course, several might be laid down, each equally fixed and equally valuable for the end in view; or, what would probably better accomplish the same end, we might graduate students in a larger number of departments, and thus secure a greater variety in the courses, and a better adaptation to the wants of particular students.

But these are suggestions which, if of any value, will in time be worked out by the Faculty of the school, and presented for your consideration.

The year has been one of marked progress in our educational work, and I close this report by thanking every member of the Corps of Instruction for the able and faithful service he has rendered in securing this satisfactory result.

Respectfully submitted,

J. D. RUNKLE.

SECRETARY'S REPORT: 1872-73.

In conformity with article 16, section 4, of the By-Laws of the Corporation, I herewith present the Annual Report of the Transactions and condition of the Institute for the eleventh year, 1872-1873.

There have been held during the year thirteen meetings of the Society of Arts; these have not been as well attended as usual, on account of the derangement of the business of many of the members by the fire of November last, as well as the prevalence of a dreaded epidemic, and the uncommon severity of the winter.

Dec. 11, 1872. Mr. John A. Coleman read a paper on the Application of Mill Heating and Fire Protection to the Warehouse System.

Dec. 12. Mr. Ernest Edwards made a communication, illustrated by many specimens, some executed at the meeting, on "Photography in the Printing Press," or the Heliotype Process.

Dec. 26. Mr. Wm. B. Whiting read a paper on Warehouse Construction, with special reference to protection against fire.

Jan. 9, 1873. Mr. E. H. Hewins continued the subject of the proper construction of fire-proof buildings, and of the best way to extinguish fires in the quickest and least destructive manner.

Jan. 23. Prof. W. A. Rogers, of Cambridge, exhibited and explained a machine of his own invention, for determining personal equation, or the interval which elapses between an event and its perception by an observer.

Mr. Crandall exhibited working models of machines, invented by himself, for simplifying and expediting some of the processes in the manufacture of pianos.

Prof. Pickering described a new Difference Engine, or Tabulating Machine, the invention of Mr. George B. Grant, of Cambridge, comparing it with the celebrated Difference Engine proposed by Sir Charles Babbage some fifty years ago.

Feb. 13. Mr. A. Tacchella exhibited a working model of his combined fire ladder and escape, and hose elevator.

Mr. S. P. Sharples then addressed the Society on the subject of the disposal of slaughter-house waste and dead animals by means of chemical processes, which convert them into various non-offensive compounds of great value in the industrial arts.

Feb. 27. Mr. McMurtrie read a paper, illustrated by drawings on the blackboard, and by an extensive series of specimens, on the Tilghman process for engraving and cutting glass, stone, etc., by the use of a sand blast.

March 13. Mr. Edmund H. Hewins made a communication, illustrated by diagrams and drawings, on the Gilbert Elevated Street Railway of New York City.

Mr. Henry A. Page explained his system of suspended street cars, by which many of the inconveniences and expenses of the ordinary horse-railroad may be avoided.

March 27. The business of the meeting was the report of a Committee appointed to consider the best method of securing a greater interest in, and fuller attendance at, the meetings of the Society.

April 10. Mr. C. Millard made a communication on the Diamond-Saw Quarrying Machine, adapted to all kinds of rock cutting and dressing, illustrated by a carefully made sketch on the blackboard of nearly the size of the machine. What the

saw does for wood, it is claimed that this machine will do for stone.

April 24. Col. Jacob J. Storer addressed the Society on the best means of disposing of the waste of slaughter-houses and other animal refuse of large cities.

May 8. Mr. J. R. Robinson made a communication on the cause of the explosion of steam boilers, analyzing several cases which he had been called upon to examine.

May 22. Mr. H. P. Langley exhibited a new form of grate bar, by which ashes and light clinkers may be removed without opening the fire door.

Mr. Grosvenor exhibited in operation a very simple and effectual form of steam pump, with no movable parts except three or four automatically moving ball valves.

Mr. McMurtrie exhibited in operation, and explained by diagrams, Nye's Automatic Steam Vacuum Pump, now in use in this city for raising salt water.

There have been elected during the year 9 associate members, the list now comprising 336 members. One life member and 4 associates have died during the year, viz., Messrs. Savage, Dexter, Frothingham, Lynch and Sears. Nine have resigned during the year.

The School of Industrial Science has had a very satisfactory attendance, 375 students having enrolled themselves, viz.: Resident Graduates, 5; Regular Students of 4th Year, 32; of 3d, 27; of 2d, 61; of 1st, 115. Students not Candidates for a degree and Special Students, 4th Year, 24; 3d, 42; 2d, 31; 1st, 16. Students in Practical Design, of whom 13 are females, 22; total 375, or 111 more than last year; of these nearly five-sixths are from Massachusetts, principally from Boston and vicinity; 25 others are from New England, viz., from Maine, 5; Vermont, 4; New Hampshire, 7; Rhode Island, 6; Connecticut, 3; from other States there are, from New York, 9; Pennsylvania, 7; Ohio, 14; Illinois, 7; Kentucky, 3; Minnesota, 3; Indiana, 2; California, 2; Kansas, Delaware, Wisconsin and

Iowa, 1 each; from foreign countries, the Azores and Teneriffe, 3; Japan, 2; Sandwich Islands, 1; and British Provinces, 1.

Thirty-three professors and teachers have been connected with the school, and several advanced students have rendered assistance in drawing and surveying. The fees from students will reach $47,000, about $10,000 more than last year, and considerably more than the estimate of the Treasurer in May last.

The School of Design, under the auspices of Mr. Lowell, has proved a great success, and bids fair to be one of the most important aids to the industrial arts.

The Lowell courses this year have been as follows: 18 lectures on Descriptive Geometry, commencing Nov. 11, by Prof. Lanza; 18 lectures on Systematized French Pronunciation, French Conjugation and Idiomatic French, by Instructor Lévy, Nov. 11; 18 lessons in Machine Drawing, by Instructor Schubert, Nov. 12; 10 lectures on the Laws of Life and Health, by Prof. Kneeland, Nov. 12; 10 lectures on Modern History, by Prof. Atkinson, Nov. 13; 18 lectures by Prof. Hunt, on Chemical and Physical Geology, Nov. 29; 18 lectures on Experimental Mechanics, by Prof. Cross, Dec. 16; 10 lectures on Logic, by Prof. Howison, Jan. 22; 18 lectures on Translation of Lessing's Nathan the Wise, by Instructor Krauss, Jan. 20.

The same causes operated, as in the case of the Society of Arts, to render these courses less well attended than usual.

The Corporation have held eight meetings during the year, including the one of to-day, May 14th.

At the meeting of June 13, 1872, it was voted to establish advanced courses of study, and to change the title of the Degree conferred by the Institute to that of Bachelor of Science.

Sept. 11, 1872. Voted to establish the "Lowell School of Industrial Art," Mr. Lowell having offered to pay the salary of the head of said school.

Dec. 11. Solid Geometry and the rudiments of French, were added to the requirements for admission, and the fees were raised to $200 per annum. Mr. Charles P. Otis was

appointed Professor of Modern Languages, and the detail of Lieut. Zalinski, U. S. A., as Military Instructor, was requested from the War Department. It was also voted that the financial year of the Institute begin and end on the 1st of October in each year. The use of the large hall was granted to Trinity Church as a place of worship.

Dec. 27. A Committee was appointed to petition the Legislature for a piece of land between Huntington Avenue and Boylston St., for a Chemical Laboratory.

Feb. 12, 1873. The Degree of Bachelor of Science was conferred on eleven graduates of the Institute.

April 9. A letter was read from the Governor's Secretary, stating that the land asked for had been granted. At the same meeting Mr. Bowditch read a letter from an unknown friend of the Institute, giving the sum of $25,000, to be devoted to the payment of salaries.

A Committee was appointed to obtain plans for the new building, and also one to devise means for raising the money for its erection.

SAMUEL KNEELAND, *Sec.*

REPORT OF THE WORK IN LOGIC AND THE PHILOSOPHY OF SCIENCE.

To the President of the Massachusetts Institute of Technology.

I have the honor to present the subjoined account of what has been done in this, the first year of my duties as Professor of Logic and the Philosophy of Science, and of what I shall aim to accomplish in the future.

On the opening of my work in October, 1872, it became at once manifest that, under the existing arrangement of the courses of study in the several departments of the Institute, sufficient time for preparing my subjects was absolutely beyond the control of the great majority of the students in the two upper classes. After careful consultation, I asked and obtained the warrant of the Faculty to adjust my plans of instruction to the temporary exigencies of the general work by confining all preparation, on the part of the students of the then Third and Fourth Years to my actual hours of lecture, and by reducing the scale of work, both in amount and in minuteness, to correspond with this change. I mention the foregoing facts, to account for what might otherwise seem the small amount of instruction attempted this year in the Third and Fourth Classes. The actual work in these has been as follows: —

I. In the Fourth Year, so much, and only so much, of the Theory of Induction has been given, as seemed absolutely indispensable for a foundation of the Philosophy of Science. This

has included a pretty thorough discussion of the conception of Induction as a mental process, of the processes subsidiary to it— Observation and Experiment, Classification, Nomenclature and Terminology, and Hypothesis — and, finally and most especially, of the nature, conditions, and canons of the Five Scientific Methods — those of Agreement, of Difference, of Double Agreement, of Concomitant Variation, and of Residues. The method of instruction has consisted in the careful reading with the class of Fowler's text,[1] in the explanation, illustration and expansion of the same, so far as required and as permitted by the allotted time (two hours a week for the first half of the year), and in the careful and thorough criticism of the doctrines advanced by the author, or quoted by him. Free questioning on the part of the class has been encouraged, and oral examinations have been conducted from lecture to lecture, as the occasion seemed to require; these have been supplemented by one or two written ones. The precise objects aimed at have been (1.) to furnish each student with such a clear comprehension of the process of Induction, and of its conditions, as would render him distinctly conscious of his mental steps in any scientific investigation which he might be called to conduct; and (2.) to teach by a thorough example the true method of reading and mastering a subject, as presented by a scientific writer.

At the final examination for degrees, held May 27, 1873, the following paper was presented to the class. It will enable one to form a very fair judgment upon the nature of the work attempted, as it is similar in character to the paper used at the semi-annual examination, though somewhat more difficult.

[Examination of the Fourth Year's Class in Logic, May 27, 1873.]

Examine carefully the following investigation, and write down the *precise* proposition sought to be established by it. Then state by which of the Four Experimental Methods the reasoning is governed, and write out an analysis of the investigation, so as to show exactly

[1] A *Treatise on Inductive Logic*, by Thomas Fowler, M. A., Oxford: at the Clarendon Press.

the points in which it agrees with the Essential Elements of the Canon corresponding to the Method.

"The north-east wind is known to be specially injurious to a great many persons. Let the inquiry be — What circumstance or quality is this owing to? By a mental analysis we can distinguish various qualities in winds — the degree of violence, the temperature, the humidity or dryness, the electricity, and the quantity of ozone. We then refer to the actual instances, to see if some one mode of any of these qualities uniformly accompanies this particular wind.

"Now, we find that, as regards *violence*, easterly winds are generally feeble and steady, but on particular occasions are stormy; hence we cannot attribute their noxiousness to the intensity of the current.

"Again, while often *cold*, they are sometimes comparatively *warm;* and although they are more disagreeable when cold, yet they do not lose their injurious character by being raised in temperature; so that the bad feature is not coldness.

"Neither is there one uniform degree of *moisture;* they are sometimes wet, and sometimes dry.

"Again, as to *electricity*, there is no constant electric charge connected with them, either positive or negative, feeble or intense; the electric tension of the atmosphere generally rises as the temperature falls.

"Farther, as respects *ozone*, they have undoubtedly less of this element than the south-west winds; yet an easterly wind at the seashore has more ozone than a westerly wind in the heart of a town.

"It would thus appear that the depressing effect cannot be assigned to any one of these five circumstances. When, however, we investigate closely the conditions of the north-easterly current, we find that it blows from the pole to the equator, and is for several thousand miles close upon the ground; whereas, the south-west wind, coming from the equator, descends upon us from a height. Now, in the course of this long contact with the ground, a great number of impure elements — gaseous effluvia, fine dust, microscopic germs, etc. — may be caught up and remain suspended in the lower stratum breathed by us. On this point alone, so far as we can at present discover, is the coincidence of all the instances of the east wind constant and uniform.

"If, then, our elimination be supposed complete, there is a proof that the deleterious influence is due to the circumstance last named."

Does the investigation satisfy the conditions of the Canon, and is the conclusion valid?

The responses of the class to this paper were highly satisfactory, almost without exception; as indeed they also were, in almost as high a degree, to the examinations previously conducted.

Nothing more in Logic or Philosophy has been attempted with this class, and it is therefore necessary to show how my time has been spent with them during the second half of the year. It was my desire to advance somewhat into the detail of the Philosophy of the Sciences, especially into that of Mathematics; but the Government having expressed a strong desire that the subject of Political Economy should be presented, at least in clear outline, and having requested me to step aside from the strict line of my labors long enough to perform the duty of giving the necessary instruction in that subject, I complied, but found it impracticable to accomplish anything valuable without occupying all that remained of my time with this class. The time since February, 1873, has accordingly been given to Political Economy. I have read with the class, in a manner similar to that pursued in the case of Fowler's *Logic*, Mr. Walker's treatise on the *Science of Wealth*, taking pains to present the points in which other leading writers differ from him, and to develop with especial clearness both sides of the great dispute between Protection and Free Trade. The class have shown great interest in the subject, and at the final examination, held May 12, 1873, not a single member was conditioned, while the great majority passed at a very high grade. The paper set is subjoined, and I cannot at this point forbear remarking upon the general excellence of the English writing in the papers presented by the class; it was terse, clear, and in almost every case, noticeably free from defects of every kind.

[Examination of the Fourth Year's Class in Political Economy, May 12, 1873.]

1. Show how the action of the three elements — Desire, Labor, and Wealth — renders the realm of Political Economy an ever-expanding one, and how it is that they render Political Economy a *positive* science.

2. Define *Wealth*, in its strict, scientific sense.

3. Define *Value*, show what are its two essential conditions, and point out the ambiguity, in the ordinary use of the term, which must be carefully avoided in Economic Science.

4. Define *Labor*, and prove that the service of slaves, or any other involuntary work, is not labor in the economic sense.

5. Define *Capital*, and show why the distinction sometimes made between "active" and "idle," or "productive" and "unproductive" capital, is futile.

6. What are the three principal modes of Production, and what the three conditions of its highest success?

7. State some of the principal advantages of Division of Labor, show its limitations, and point out some of its evil tendencies, which need to be counteracted.

8. What is the conclusive argument in favor of Free Trade, from a strictly economic, or merely *monetary* point of view; and what is the equally conclusive argument in favor of Protection, as a policy sometimes absolutely necessary, though temporary?

9. What are the essential conditions of a good Currency? Show that neither a Credit Currency nor a Mixed Currency can satisfy these conditions, and why. State the advantages of a Mercantile Currency over one of Coin.

10. State some of the advantages and disadvantages of the Direct and the Indirect methods of Taxation, and show why it is necessary always to make the indirect method Discriminating.

II. In the Third Class, the work of the year has been confined to the elements of Formal Logic. We have covered the ground of the Classification of Terms, of the Distinction between Extent and Intent, of Definition, of Division, of the Classification of Propositions, of their analysis into Subject, Copula, and Predicate, and have advanced into the Doctrine of Inferences as far as through the principles of Immediate Infer-

ence, so-called. The method pursued has been essentially the same as with the Fourth Class, except that there has been a more decided effort to teach principles by examples. Fowler's text[1] has been made the basis of the instruction, and has been amplified when necessary, and criticised where it seemed to call for that treatment. The variations of view among the leading logicians have been presented, the different doctrines criticised, and the whole presentation of principles has been supplemented by oral and written practice upon examples. The time has been too short for the performance of the work in the best manner, and yet, considering all the circumstances, I have been highly pleased with the results. Subjoined are the two examination-papers used at the semi-annual and annual examinations respectively, from an inspection of which the scope and character of the work may be seen. The success of the class is indicated by the fact that only one member was conditioned at the final examination.

[Examinations of the Third Year's Class in Logic.]

I.—Semi-Annual Examination, January, 1873.

1. Write an original example, not in blank symbols, but in significant real terms, of each of the proposition-forms *I* and *Y*.

2. Point out all the respects in which the following proposition violates the conditions of a formal-logical definition: —

A Constitution is a document revealing the principles from which a National Life germinates, and which control the organization of a community for the purposes of government, or of the administration of the public interests.

3. Give an example of correct definition, by defining with precision a *Mathematical Limit.*

4. Point out all the errors in the following professed Division: —

The members of a community into Capitalists, Operatives, Catholics, Protestants, Merchants, Mechanics, and Agriculturists.

5. Give a correct and *complete* division of *Plane Figure*, down to its *infimæ species.*

[1] A *Treatise on Deductive Logic*, by Thomas Fowler, M. A. Oxford: at the Clarendon Press.

6. Reduce the following proposition to its regular logical form, so as to exhibit distinctly its subject, copula, and predicate: —

None but the brave deserve the fair.

7. Reduce the same to its logical skeleton, by substituting literal symbols for its subject and predicate, specifying the precise words for which the symbols stand, and then name the form (A, E, I, O, U, or Y) under which it falls.

8. Apply the directions in Question 6 to the following proposition: —

All that glitters is not gold.

9. Apply to the same proposition, the directions in Question 7.

10. Rewrite the proposition of Question 8 in such words as to bring out distinctly (1) its meaning *in extenso*, and (2) its meaning *in intenso*.

II. — *Annual Examination, May*, 1873.

1. In the following expressions, specify which of the italicised terms are General, and which are Singular: —

None but *the brave* deserve the fair.

Man's inhumanity to man makes countless *thousands* mourn.

A *bird* in *the hand* is worth two in the bush.

2. In the following, distinguish between the italicised terms that are Distributed, and those which are Undistributed, stating in each case the principle which determines the decision: —

Socrates was *wise*.

No *man* is *infallible*.

Some *men of genius* have been destitute of talent for affairs.

3. Of the terms *Animal* and *Brute*, which has the wider Extent, and why? Of *Conic* and *Ellipse*, which has the deeper Intent, and why? Why cannot the Extent or Intent of *Body* and *Spirit* be compared?

4. Divide the term *Students of the Massachusetts Institute of Technology*, down to its *species infimæ*, in accordance with the rules of Logical Division.

5. Point out the respect in which the following statement violates the Laws of Definition: —

A T-square is a sort of straight-edge.

6. Write (1) the Residuals, and (2) the Contraries, of the following terms: —

North, Probable, Black.

7. Write all the possible Opposites of the proposition *No philosophers are materialists*, and name the Grade of Opposition in which each stands.

8. Why would it not follow, upon disproving the foregoing proposition, that all philosophers are spiritualists? What *would* follow?

9. Convert the proposition *All observations are liable to error*, and state whether the conversion is Simple or Accidental.

10. Given the proposition *Some historians are not trustworthy*, (1) as true, and (2) as false, write all the legitimate Inferences by Opposition. Why can no Inference by Conversion be drawn from it? What is the legitimate Inference by Permutation, or Residuated Opposition?

The remainder of my work has been with the First Year's class, and has consisted in lectures upon the rudiments of Formal Logic, with especial reference to their application in the science of Language in general, and in that of the English language in particular. I felt that the attempt to present such a subject to a class at once so large and so inexperienced in such topics, and to present it, moreover, by lectures alone to a class as yet wholly without practice in taking notes, was, to say the least, an experiment. Nevertheless, from the peculiar nature of the views I felt obliged to present, no other course seemed open. I have therefore lectured to the class once each week during the entire year, giving up an hour at intervals to the business of testing, by proper questioning upon doctrines and examples, the comprehension of principles, and occasionally adding other hours devoted to a repetition of difficult matters in a more familiar form than that of the original lecture. A large, and, as it seems to me, decidedly valuable part of my work with this class, has consisted in a careful and sufficiently frequent revision of all their note-books, for the purpose of correcting errors, not merely of detail, but in the whole conception and plan of note-taking. The rapid and remarkable improvement of the class in this respect during the year, has more than repaid the drudgery of the process.

The results in the subject itself have perhaps been as good

as we had any reason to expect. From the subjoined papers, it will be seen that, while the work has been strictly rudimental, there has been no attempt to evade its difficulties. Upon the first, used at the semi-annual examination, some thirty-five were dropped or conditioned, out of a class of one hundred and fifteen. But of these, all but two made up their work successfully on the two papers marked II. and III. On the final paper, out of a class of seventy-six, three were conditioned, and none failed.

[*Examinations of the First Year's Class in Logic.*]

I.— Paper used at the Semi-Annual, January, 1873.

State under which of the Three Divisions in the Science of Language, each of the First Seven of the following statements belongs: —

I. The essential qualities of Style are clearness, appropriateness, and vitality. These it must have, no matter what the topic treated of, nor the end aimed at; what other properties it shall exhibit, will depend upon the nature of the subject in hand, the specific object to be gained in presenting it, or the special form of the composition.

II. If the thing denoted by an English verb occurs in what is called present time, the form of the verb changes to correspond with the number of the subject, provided the latter be in the third person.

III. A Noun is the name of any object of sense or subject of thought.

IV. The Possessive Case (*'s*) precedes the noun on which it depends.

V. One of the most effective means for giving vitality to style is the judicious use of metaphors; but a metaphor is an edge-tool, and the inexpert need to be wary in handling it.

VI. In the following expression from Ben Jonson's Eulogium of Shakspeare, namely, —

> ——— Soul of the age,
> Th' applause, delight, and wonder of our stage,
> My Shakspeare, rise!

all that precedes the word *rise* is the Compellative, or title of the person to whom the Imperative [*rise* (*thou*)] is addressed. *My Shakspeare* is the basis of this Compellative, and is modified by the appositive phrases, *Soul of the age*, and *Th' applause, delight, and wonder*

of our stage. It is noteworthy that this basis is complex, while the second appositive phrase has a compound base, *th' applause, delight, and wonder.* Of the Imperative, *thou* (understood) is the subject and *rise* the predicate; the copula is not symbolized.

VII. In the same expression, we may notice the forcible use of metaphor in the phrase *Soul of the age,* and the skillful metonomy in the expressions *applause, delight,* and *wonder.* Here the effect is put for the cause; Shakspeare *produced* applause, delight, and wonder, and the vivaciousness of the metonomy lies in the fact that the poet thus makes him appear so completely the life and soul of the effect he produces, as to be actually present in it, and utterly identified with it.

VIII. In the statement *Mercy is twice bless'd,* point out exactly how the Inner Aspect of Expression is exhibited.

IX. Show also in what consists the Outer Aspect, as presented in the same saying.

X. Exhibit the triune form of the proposition in the following exclamation, which Milton makes Death address to Satan: —

Back to thy punishment, false fugitive!

II. — Paper used to re-examine conditioned men, March 7, 1873.

I. In each of the following sentences numbered (1), (2), and (3), there are marked defects; in the case of each, state, *with the reasons for your opinion,* whether the defects are *logical, grammatical,* or *rhetorical:* —

(1.) The distance of the line from the origin is constant; but it's inclination to the axis of x is variable.

(2.) The line's inclination has variation in an unlimited gradation.

(3.) The inclination of the line may be changed at pleasure, and is therefore invariable; but the distance constant.

II. Point out which of the Three Forms of Universal Language is exhibited in each of the following expressions, taken as a whole: —

(4.) Because some men are hypocrites, is no reason for supposing that all men are so.

(5.) Merely to think of the hypocrisy of some men ——

(6.) Alas! to think of the hypocrisy of some men!

(7.) Just think of the villany of some people.

(8.) Some plausible people are villains at heart; because they do not hesitate to act basely whenever they feel sure that they will not be detected.

(9.) The deep-seated, crafty, unsuspected villany of many men that might be named.

III. Rewrite the following proposition in such words as, without in the least changing its meaning, will bring out distinctly the three elements of its triune form: —

(10.) A man may smile and smile, and be a villain.

III. — Paper used in Final Examination of conditioned men, April 9, 1873.

1. How many, and what, elements are to be found in every proposition?

2. How do you reconcile the apparent discrepancy between the answer you have just given, and the form of such a proposition as *We-think?*

3. And how can you make out the requisite number of elements in *Go to the ant, thou sluggard?*

4. Above all, how can you find them in such a proposition as *Bethink thee?*

5. Is this a proposition: — *Better late than never?*

6. Is this: — *Brighter than all the stars of heaven?*

7. Is this an argument: — "Smith went to California, because he wanted to try a miner's life"?

8. Or this: — "He lay down and slept; for he was weary"?

9. Or this: — "Any side of a triangle is shorter than the circuit of the other two; for it is a straight line joining the same two points that they join by a broken line"?

10. Rewrite the following argument, so as to display in their proper order the three elements of its triune form, putting down (1) the Major Premiss, (2) the Minor Premiss, and (3) the Conclusion: —

"Because the shadows point westward, it is still morning."

IV. — Paper used at the Annual Examination, May, 1873.

1. Suppose that a certain piece of English were placed before you, and that you were required to criticise it (1) in respect to *purity*, (2) in respect to *propriety*, and (3) in respect to the *coherency and consistency of its propositions and their parts*, in which of the Three Divisions of the Science of Language would the three parts of your work respectively fall?

2. Decide, with regard to each of the following expressions considered as a whole, whether it is a Term, a Proposition, or an Argument, giving the reasons for the decision in each case:—

(*a.*) If I mistake not, it is with *Meister* as with every work of real and abiding excellence, the first glance is the least favorable.

(*b.*) One of the only three men of genius that have ever lived.

(*c.*) Is thine eye evil, because I am good?

(*d.*) There could no longer be any doubt of the prisoner's guilt; for he had committed suicide at the moment when new evidence, of an important and damaging character, was about to be brought forward.

(*e.*) That the court which tries him be pure, and the jury instructed in the cause; that the work be not condemned for wanting what it was not meant to have, and by persons nowise called to pass sentence on it.

3. Write the list of the Ten Categories, in their proper order, and state their principal use (1) in connection with the doctrine of Terms, and (2) in connection with that of Propositions.

4. Decide which of the following terms are Substantive, and which Attributive:—

(*a.*) The least favorable.

(*b.*) The first glance.

(*c.*) Every work of real and abiding excellence.

(*d.*) Of real and abiding excellence.

(*e.*) As with every work of real and abiding excellence.

5. Decide which of the following terms are Singular, and which General:—

(*a.*) Court.

(*b.*) The court which tries him.

(*c.*) Goethe.

(*d.*) Fidelity.

(*e.*) Persons nowise called to pass sentence on the work.

6. In the case of the Singular terms among the foregoing, distinguish between those which are Abstract, and those which are Concretely Individual.

7. In the list of terms in Question 5, point out those which are Simple, and those which are Multiple. In the case of the latter, state whether they are Complex or Compound. Finally, see whether

there is, among any of these terms, or among their component parts, an example of a Complemental term; and, if you find one, specify it.

8. Define the distinction between the Extent (or Denotation) and the Intent (or Connotation) of a term, and illustrate it in the case of the term *circle*.

9. Resolve the following propositions into Subject, Copula, and Predicate, without enlarging, restricting, or otherwise altering the meaning of either: —

(*a.*) Goethe is by many of his countrymen ranked at the side of Homer and Shakspeare.

(*b.*) To many of them I could do no justice.

(*c.*) What work was ever as the workman wished and meant it?

(*d.*) For this purpose, the most that I had room to say is said.

(*e.*) It is not tears which her fate calls forth.

10. In each of the following, give the final import of the predicate, by naming the category under which it falls: —

(*a.*) Fidelity is all the merit I have aimed at.

(*b.*) The duty of a translator is simple and distinct.

(*c.*) Some of these I may have failed to see.

(*d.*) The hero of the *Meister* is a milksop.

(*e.*) Goethe wrote *Meister's Apprenticeship* in his forty-fifth year.

For the future, I would recommend that the work from my chair begin with the second half of the Second Year, and continue throughout the Third and the first half of the Fourth, closing with the semi-annual examination of the latter. I should distribute the topics over that period as follows: —

Second Year: — Formal Logic,—Doctrine of Terms, Propositions, and Immediate Inference.

Third Year, *First Half:* — Formal Logic, — Doctrine of the Syllogism, and of Fallacies.

Third Year, *Second Half:* — Philosophy of Science, — Theory of Induction.

Fourth Year: — Philosophy of Science, — Logical structure of the various Sciences, especially of Mathematics; Theory of the Calculus; Philosophic Place and Value of the several Natural Sciences.

Of course it is to be understood that more time is to be given to these topics hereafter than we have been able to command the present year. The student must have ample time for the preparation of the subjects which have been assigned to my chair — time additional to that occupied with me in the lecture-room. I believe, however, that provision has already been made for this, at least in part, by a re-arrangement of the details in the other courses of instruction. When all our plans are completed, I cannot but believe that this department will fully realize all that was hoped for from it by those who urged its establishment.

Respectfully submitted,

GEORGE H. HOWISON.

Boston, June 5, 1873.

REPORT OF THE DEPARTMENT OF DESCRIPTIVE GEOMETRY, STEREOTOMY, AND DRAWING.

To the President: —

The subjects composing this department were formerly distributed among several other departments; but, with the rapid growth of the school were formed into a new and distinct one, a year ago. The present is thus the first report relating to it, separately.

For this reason, as well as on account of a comparatively general unfamiliarity with the scope and meaning of its first two sub-titles, it seems due to the subject to present the matter, methods and work of the department, somewhat fully, however summarily, in a first report.

This may be conveniently done under distinct heads, as follows: —

I. *The definition of the department.* Descriptive Geometry may be popularly defined as the *geometry of drawing*; or, more exactly, as the system of principles, and exact operations founded upon them, by which all regular objects, both singly and in all possible combinations, can be so truly represented upon flat surfaces, that, from the drawing, the original can be constructed as it exists in the mind of the designer.

Stereotomy means literally the cutting of solids; as in Stone Cutting, Carpentry, and the shaping of mechanical pieces so as to produce certain motions by their combined action.

But, by the same refinement of speech by which *solid* geometry treats definite portions of space as empty volume, rather than as material bodies, stereotomy includes, in a geometrical sense, the cutting of immaterial as well as material forms, the cutting of the portion of space darkened by an opaque body, by a surface, which thus receives the shadow of that body; and the cutting of the immaterial cone of rays from a body to the eye, by a plane, which thus contains the perspective or picture of that body. Stereotomy thus embraces, in full, Shades and Shadows; Perspective; the shaping of mechanical organs relative to the motions they will produce, or the stereotomy of mechanism; the shaping of the elements of structures relative to their affording convenient and appropriate bearings, or the stereotomy of masonry, carpentry, and metal structures, as in stone-cutting, and roof and bridge articulations.

Drawing includes, *first*, the drawing of the many diagrams of a general character illustrative of the body of theory pertaining to Descriptive Geometry and Stereotomy; *second*, the preparation of finished working drawings of actual or proposed structures and machines; also free-hand and topographical drawing; and considerable preliminary drill in the merely manual operations in the use of instruments and drawing materials.

From this exhibit, it is at once evident that the department, reaching as it does nearly every member of a large institution, is an extensive one; so much so, as already found by trial, that my foremost recommendation for the future is, that at the earliest opportunity all of the *second* branch of drawing just named be coupled with Geodesy, or the whole of Engineering field practice, and set off as a new department of Geodesy and Drawing; leaving the title of the present department to be Descriptive Geometry and Stereotomy. I suggest the union of geodesy with drawing, having for many years, in a former position, seen the smooth and excellent practical working of the

obviously natural plan of putting the construction of all maps of surveys in charge of the same hands that conduct the surveys themselves.

II. *The actual present composition* of the department now defined, is as follows; the subjects being arranged as given in the four successive years of the Institute course of study: —

FIRST YEAR.

1. Construction of Problems of points, lines, polygons and circles, in plane geometry.
2. The use of drafting instruments and materials.
3. Elementary, general and applied Projections; or rudimentary and practical Descriptive Geometry.
4. Elementary Perspective, both of Forms and Shadows.
5. Elementary free-hand drawing.

SECOND YEAR.

6. Descriptive Geometry.
7. Shades and Shadows.
8. Topographical drawing.
9. Free-hand drawing.

THIRD YEAR.

10. Machine description and drawing.
11. Structure drawing from measurement.
12. Maps of land and line surveys.

FOURTH YEAR.

13. Stone-cutting.
14. Various professional drawing assigned by different departments.

III. *The work done.* Something has been accomplished during the past year in each of the above fourteen subjects, though less, it being a first and experimental year, than may be hoped for in future.

In the *first year* there were about thirty exercises per man, of mingled instruction, interrogation, or blackboard demonstration, upon the body of principles, or theory, connected with the numerous additional drawing exercises; the whole occupy-

ing about ten hours per week. In these exercises an aggregate of not less than forty rationally constructed, not copied, plates, nine inches by thirteen inches in size, were made by each student, besides the execution of many plates in Free-hand Drawing.

In the *second year* there were about forty class exercises, as above, on the theory of the subjects pursued, connected with the construction of about sixteen plates, ten inches by fourteen in size, in Descriptive Geometry and Shades and Shadows, besides those made in Free-hand landscape and object drawing, and in Topographical drawing.

In the *third year*, owing to excess of other work, a little only was done in Shades and Shadows and in Machine Drawing, in the first half of the year. But a very satisfactory beginning was made in the second half, with the drawing of various roofs, bridges, and other structures in the vicinity, suited to the various professional courses chosen by different students. The class entered on this work with gratifying and commendable zeal, and made drawings, from measurements of a drilling machine, the new Providence Railroad Depot roof-truss, the Lowell Railroad drawbridge, an iron road bridge at Waltham; and of smelting and gas furnaces, all under instruction; also maps of surveys.

With the *fourth year* class, various hindrances prevented more than a bare beginning of a course in stone-cutting; and the construction by each student of one bridge drawing, generally one of several bridges visited during the preceding summer.

To the three regular architects of the Third and Fourth Years united, a short course in Higher Perspective of Forms and Shadows was given, with the peculiar pleasure always arising from the instruction of a small class of interested and uniformly qualified students. A short special course in Elementary Projections of bodies and of their shadows was also given to the Special students of architecture belonging to the Third Year.

IV. *Remarks and suggestions.*

a. The force of instruction for accomplishing the foregoing work has consisted of one professor, three official assistants — two of whom gave but a part of their time to the department — and six student assistants. This may or may not seem a large force, but it must be remembered that while the occupants of some chairs seldom or never come in contact with more than a dozen students, the present is one of several of the more comprehensive departments, whose instructions extend to nearly all of our three hundred and fifty students.

It seems generally better to have official, rather than student instructors; and, with the present number of students, I would urge the advantage of employing the full time of three official assistants, or its equivalent, with from two to four student assistants, according to the nature and amount of their services.

b. Methods. These have embraced, under the head of *instruction*, brief familiar exposition, accompanied by Models and Diagrams and the expounding of text-books, with careful pointing out of cardinal principles and directions for proper use of the book in order to gain a clear view and firm grasp of the subject. Also under the head of *recitation*, individual and general interrogation, blackboard demonstrations, and regular and informal written examinations.

In reflecting on the character of the many examination papers looked over during the year, it has occurred to me, often and forcibly, that in some things they are not a full substitute for oral examinations, though on the whole decidedly preferable, independently of the size of the school. Their strong point, to my mind, is in the opportunity they afford for each man to tell substantially all he knows of the subject in hand, or at least enough to enable the examiner to form, generally, a sure judgment in each case.

Their weak points thus far noted are two. First, their undoubted tendency to encourage a slighting of daily term work, and a "cramming" at the end, on the part of all who do not study from principle, or fondness for learning; that is, if

the *final* term papers, only, are wholly or mainly relied on to determine the student's standing. This defect could be obviated by making the student's standing depend on the mean of the results of all the tests applied to him, or at least of all his written examinations.

The second defect, of very different nature from the last, is that written papers are liable to betray perplexing ambiguities as to what the writer really means, and wasteful misunderstandings of either the point or the scope of the questions; defects arising not from obscurity in the question to the well-prepared student, but to a mistiness or incompleteness in a less perfect student's knowledge, while nevertheless he is not grossly deficient. Now any exact subject may be said to embrace facts, principles, and problems. The latter only would seem to be most fully provided for by examination papers. But in ten minutes, by the clock, from twenty to forty questions, by actual count, according to their character and the readiness of the student, can be asked on facts and principles in which ambiguities and misapprehensions can, unless in cases of real deficiency, be instantly corrected, and a very telling exhibit secured of the quality of the student's command of his subject. Now it takes at least ten minutes to look over an examination paper. If, then, some way could be devised to divide ten to fifteen minutes between oral and written examination, I would submit that more comprehensive and certainly decisive results could be attained, to say nothing of the superior life and interest of an oral examination.

c. New models. A perfect set of models can doubtless only be built up gradually, as found by experience to be wanted. The more immediate needs of the department in this regard are, a set of about fifty cheap, simple objects, such as any carpenter can make, for use in drawing perspectives of actual objects, from measurement; a couple of bridge models costing about $150 each, and a small appropriation, to be drawn upon from time to time for approved and specified models in Descriptive Geometry, Mechanical Elements, and Stone-cutting.

The foregoing are all the topics that have occurred to me as being of interest relative to my department, to those having the welfare of the school in charge; to whom, and chiefly to yourself, they are respectfully submitted.

S. EDWARD WARREN,

Prof. of Descriptive Geometry, Stereotomy, and Drawing.

DEPARTMENT OF ENGLISH AND HISTORY.

Pres. J. D. Runkle:—

SIR:—I hereby present the following report of my doings during the past year in the departments of English and History.

The difficulty of securing a sufficient amount of time for English studies has continued to embarrass me, and must continue to do so, so long as the preparation for the school continues so imperfect. Practically a large majority of our regular students have to crowd four-and-a-half to five years' mathematical and scientific work into four years; and this leaves but a small amount of mental energy to be devoted to studies not strictly professional. There is one, and only one remedy for this difficulty, and that is a better preparation; and that not more, or even so much in English and mathematical as in elementary scientific study. In consequence of the very defective condition of school instruction in science in this country, our students have practically to begin the study of the very rudiments of physics, chemistry and the different branches of natural history at the age of sixteen or seventeen, a period of life at which, if our schools were perfectly organized, these elements would all have been acquired. By this postponement these studies become unnaturally difficult of acquirement, and the necessity of making up these untimely arrears of professional study stands in the way of the success of the English department, by depriving it

of the time which might otherwise be devoted to English studies. An addition has this year been made to the requisites for admission on the side of mathematics: it is to be hoped that the time is not far distant when improvement in school teaching will allow us to assume the possession of a reasonable amount of knowledge of the elements of physical science on the part of young men of the age required for admission.[1]

Till that time comes, no proper balance can be established between English and scientific studies within the school. The time required for making up arrears in professional studies *must* be taken from that which should be devoted to general training. The professional student comes for a distinct purpose; he wishes, for instance, to be made an engineer, and he must be trained so thoroughly in engineering studies that his bridge will not break down through faults of construction. It would be small comfort to his employers if that should happen, that he could report in Addisonian English, and with unimpeachable logic the precise reasons why it broke down. It is better, if the choice must be made, even that his report should contain English words misspelled, through the defects of his primary school learning, than that his bridge should prove defective; though his literary deficiencies cannot be considered otherwise than unfortunate, and the misspelling engineer can hardly claim that he has received a complete or symmetrical education. All that can be said is that his not having received it within four years cannot be imputed as a fault to the Institute of Technology.

What course to take under such circumstances has been to me from the beginning a very puzzling question. To exact from the students the amount of mental effort which would be required by a course of English studies pursued with the same thoroughness as is required in their scientific studies, is obviously impossible; for the complaint is now very general that our students are overworked, and to add to minds already over-

[1] Even now I think it would be feasible to require an entrance-examination in one or more of the excellent "Science Primers," now in course of publication in England.

burdened with scientific study the amount of labour required for the thorough study of all the great subjects which a properly conducted english course contains, would be simply to break down the student altogether. On the other hand, to reduce requirements in English to the paltry minimum of correct spelling, and the writing of business letters, would be to abandon all claim on the part of our institution to being called a place of liberal education.[1] I cannot claim that I have completely overcome the difficulty, for it is in its nature unsurmountable; and a teacher in the English department of the Institute must for the present, be contented with very modest, not to say incomplete and imperfect results. One consideration has guided me in the course I have pursued in my literary and historical instruction, and it is a very important one in connexion with such studies, that they are precisely of a kind where much may be done, by proper effort on the part of the instructor, to implant taste and excite curiosity even where the opportunity is wanting for systematic or exhaustive study. The mathematics required by the engineer are a precise and definite subject, to be thoroughly mastered by the student within a given period, as an absolutely essential qualification for his degree. A knowledge of literature and history is no such definite quantity, and by its very nature is not to be arrived at by such precise methods. Taste cannot be taught, nor a knowledge of history be communicated in twelve or any other definite number of lessons, though a knowledge of geometry may; but it may make an infinite difference to the student in after life whether some love and appreciation of literary and historical studies was or was not implanted in his mind in the course of his school education; and that love and appreciation may be instilled by methods different from the rigid and exhaustive ones required in the purely disciplinary part of his studies. It may

[1] It is a point upon which I am not qualified, and do not presume, to give an opinion how far our present scientific courses might be curtailed of scientific superfluities, but I am clearly of opinion that if there are any such superfluities they should be sacrificed in preference to any part of the student's general training.

fairly be maintained, therefore, that while in the latter case the main stress of the labour falls upon the student, and his success depends upon the amount of his hard work, there is learning of a different kind where the burden of the labour falls upon the instructor, and his difficult task is so to digest his materials as to produce a valuable result with only a minimum of effort on the part of the pupil. This seems to be the part to be played by instruction by lectures on subjects which cannot, either through their very nature, or through adverse circumstances, be dealt with by more rigorous methods. And in my judgment it would be a gross mistake to undervalue such instruction, if only it be good of its kind. From the very nature of things, and the vastness of the field of knowledge, every man's acquisition must consist of two parts, that which he knows systematically and thoroughly, and that which he knows partially, and only well enough to appreciate and desire to know better. To be equally master of all subjects, is given to no finite mind. It is much, if in education we teach the student to avoid the presumption of undervaluing the subjects with which he is unacquainted. That the student of science should at least be partially acquainted with literary and historical studies is infinitely better than that he should have no knowledge at all; and where a taste for such studies is not by some means implanted in school or college, it is rarely, and by accident, that it is acquired amidst the engrossing occupations of after life.

Such a course will undoubtedly be inferior in point of systematic thoroughness to the professional part of the student's instruction. It will draw less on the memory, while, on the other hand, it will aim to cultivate taste and judgment, excite curiosity, and lead to a love of extra professional reading and the acquisition in after life of knowledge on subjects which should interest the student as a man and a citizen. Many of the topics it deals with are such as had better not be handled by rigidly systematic methods; a taste once excited, a complete knowledge must be left to the voluntary efforts of after years. To make enforced tasks of what should be pleasurable mental efforts — ef-

forts which are nothing if not pleasurable — is the way in which literary instruction is too often overlaid and smothered by scholastic pedantry. Some of the best results of these studies are such as cannot well be gauged by competitive examinations or exhibited in answers to sets of printed questions.

I do not mean that such instruction can dispense with all labour on the part of the student, or that there are no methods of testing its results; I only mean that the amount of his voluntary labour may more safely be reduced to a minimum and that the amount of absolute knowledge must be very much less than that of the subject on which the stress of his mind has been exercised. Even though it may be impossible for the student to acquire the same amount of knowledge of the details of history as of the details of chemistry, he may at least gain at school an adequate conception of what the study of history really is, may have it exemplified by the more or less detailed treatment of some one period, may acquire something of what may be called the historic sense, and the habit of looking at political and social questions, whether of the present or the past, from a historic point of view. This is not every thing; but it is better than entering life without any historic training, or with only the schoolboy notion of history as being a dry collection of names and dates. In one sense it is superficial; but in another sense such instruction, addressed to young men whose minds are beginning to mature, and who are learning to think independently on important subjects, may be made to contribute to one of the most precious results of all training, namely, the habit of vigorous independent thought on subjects outside the narrow limits of their professional practice.

It has thus been my not very easy task to try to awaken a loving and real interest and an adequate appreciation of studies in the pursuit of which I could not throw the burden of much labour on the students themselves. I have heretofore erred mainly in attempting too much — not too much for what the Institute ought to be, and is destined to become, but too much for what it really is at present. The experience of a good many mis-

takes has enabled me to improve somewhat this year upon the results of the past sessions, and to report more definitely what I can reasonably expect to accomplish in the future.

I began this year with the new class with instruction from a school treatise on rhetoric and composition. This is not properly work for the Institute, but it may fairly be placed beside the necessary review of algebra and geometry with which the mathematical work begins. Every well-instructed young man of sixteen or seventeen should bring with him, as the result of the last years of his high school training, fair ability to write his mother-tongue, and a good knowledge of the elementary principles of rhetoric. It would be making a liberal estimate to say that fifty per cent. of our classes have attained such a standard, and it is a difficult question to answer, where a class has to be instructed as a whole, whether the instruction should be addressed mainly to the superior or to the inferior half. Where a class cannot be graded according to proficiency, the practical result is a compromise, which sometimes bears rather hard on the older and superior students: but my judgment inclines me more and more to the plan of taking up my subjects as nearly as possible at the point where I ought to begin, supposing the elementary instruction to have been altogether satisfactory. To do otherwise is to put a premium on insufficiency, and to degrade the function of the Institute. The bad spelling of a portion of the students has called forth much criticism, but it is a question whether the true remedy is to set students of seventeen down to spelling-lessons again.[1] So elementary lessons in the structure of sentences suited to the capacities of children furnish very uninviting food to young men. Young men cannot be turned into children again, and it is not desirable that they should be. Nature and life have been maturing their minds if school has not been instructing them

[1] For the benefit of students who have not studied Greek and Latin, I purpose hereafter to give some special lessons in the spelling and derivation of technical terms derived from those languages, the department in which the students' spelling is apt to be weakest.

properly, and though the loss arising from imperfect elementary training may not be wholly made up by any plan, yet I am confident that the principle of taking up my subjects in a manner adapted to the student's age rather than to his want of literary attainments, by producing a more living interest in the subject, involves less loss than too much belated attention to the making up of elementary deficiencies. Either doctrine, it is true, may be carried to an extreme. A teacher may, on the one hand, easily lecture over the heads of his pupils, while he may on the other, destroy all vital interest in the higher and most valuable parts of his subject by a too pedantic attention to petty details. I have tried to adopt an intermediate course. While taking the ground that the Institute does not offer itself to the public as a teacher of spelling, or punctuation and the rudiments of grammar and composition, I have given as much incidental help as possible, by causing written exercises to be corrected, and by going rapidly over the elementary parts of a school rhetoric.

I proceed, however, to a more mature and manly style of exercises as soon as possible, throwing the burden of making up elementary deficiencies from that time upon the student himself. These elementary deficiencies have arisen mainly from carelessness arising from lack of interest in school lessons, and make themselves up very rapidly whenever a living interest in literary subjects has once been excited. Deficiencies in spelling are made up if the student acquires a habit of reading; and the power of expressing his thoughts in clear and simple language is the gradual result of his whole mental discipline, when it is accompanied by even a minimum of practice in that direction. The power of expressing thoughts in writing on any subjects on which they have ideas to express, possessed by our present senior class will compare, I think, not unfavorably with that of any similar body of young men who have had no more time to bestow upon the subject than they have had.

I attach but little value to the writing of "Compositions," or the study of treatises on rhetoric after the usual fashion of

our schools. It is the cardinal principle of all good writing that a man must have something to say, and the desire to say it. Young men who have read and thought but little, have very little to say, and with them the enforced practice of composition degenerates into the habit of diluting a very few thoughts with a great number of words, than which no habit can be more fatal to good thinking. It would seem wiser to prepare for the time when they may themselves have something worth saying by occupying them with the study of writers of established excellence. And in this way every good manual in every department of study, except the most technical, is really a constant and most valuable exercise in the study of English; and the learning to think clearly on scientific subjects, is excellent training for thinking clearly on subjects non-scientific. It is in this way I am glad to explain the real progress made by our students in their matters of English where so little labour can be directly bestowed on the subject.

What can be accomplished directly amounts practically to this:—A review, at the beginning, of the rules for good writing laid down in the Rhetorics, accompanied with an insufficient amount of practice. With the Rhetorics still in hand, as books of reference, I propose to follow this with the critical reading of good specimens of modern English as studies in style and expression, with the occasional task of a written analysis of some good specimen of an English essay, or an original paper on some subject previously discussed in the class-room. These practical exercises are accompanied by a series of lectures on the history of English literature, which take the shape of a commentary on some short manuals of English literature and English history, which the students will be required to have in hand simply as books of reference. *Lessons* in such manuals are, in my judgment, worse than futile. The only labour required of the students in connexion with these lectures, will be that of taking notes, and the examinations will be conducted with the students' manuals and note-books open before them; the examination not being intended as an exercise of memory,

but as a test of their interest, their taste, their attention and good judgment. The want of a lecture-room equipped with proper facilities for writing, has hindered me from fully realizing this plan; and I respectively suggest that such a lecture-room is an absolute necessity to the English department.

The course in History has been conducted on substantially the same plan, except that for the sake of economizing time and assisting students in their study of foreign languages, the manuals used have been in the French language.

With the second class I have devoted the two lessons per week to the subject of modern history, beginning with the middle of the fifteenth century, and using the French "Histoire des Temps Modernes" of Duruy, as my manual. My custom has been to translate it slowly with oral comments, the class having the text in their hands. This was the exercise for about one-half the time, the class being required to make each week a short bit of written translation as an exercise in English. The other half has been occupied with lectures and oral lessons on the period in hand, with abundant reference to collateral reading. I have endeavored, in my treatment of the period to which we have confined ourselves, to give the students my idea of the proper method to be pursued in studying history, if they should have leisure for it hereafter, and of the true objects to be kept in view as the proper aim of the study. I have connected the study of a past era with as much information respecting the present condition of the countries as the time allowed. Having been obliged to give these lessons to a large class in a lecture room destitute of any accommodations for writing, I have not been able this year to insist upon as much systematic note-taking as I could have wished.

I have devoted the one hour per week assigned me with the third class to a similar translation with oral comments of Guizot's "Civilization in Europe." The book is the best I can find for the purpose, that of giving a brief and clear outline of the philosophy of the history of modern Europe to students who have not time to study it in detail. It is also a model of

perspicuous style, and it is the general verdict of the class that they have derived much assistance in mastering the language from this sort of exercise.

With the fourth class I have occupied my single hour per week chiefly with the discussion of subjects connected with contemporary history and politics. During the first half of the term the students themselves frequently occupied the hour with the reading of their own papers — reports on topics selected by themselves, or abstracts of pamphlets or review articles loaned to them by me for the purpose. Very good papers of this kind were read to the class, and it is very much to be regretted that more time cannot be devoted to such exercises. During the latter part of the term I have given a few lessons on contemporary history, based upon the statistics of Martin's Statesman's Year-book, with a view to making the students somewhat familiar with the present aspect of European affairs and with the resources and present social and political condition of the leading nations. I am greatly impressed with the importance of making a knowledge of the living history of the day the leading object of the historical instruction in such a school as ours.

The use of French manuals has been so far successful that I intend to try the experiment of a German manual as the foundation of my lessons on constitutional history to the fourth class, next year.

With the students in the department of "Science and Literature" I have read Shakespeare's Merchant of Venice and selections from Chaucer's Canterbury Tales, in the carefully annotated editions published in the Oxford Clarendon Press Series of English Classics, reading along with them some good specimens of criticism. It would be difficult to make Shakespeare and Chaucer otherwise than interesting, and the exercises are very well as far as they go. But it is, I think, much to be desired that English studies should eventually be made to play a leading and not a subordinate part in the course in "Science and Literature." The students who enter this department

are, as a rule, not looking forward to the practice of either of the technical professions, but come to the school rather for purposes of general education, and with the desire to procure for themselves the best general preparation for active life. They are not therefore under the same pressure in regard to purely scientific study as the students who are aiming at a technical degree. I am of opinion that the "Science and Literature" course therefore should be something more than what it is at present, a mere miscellany made up of odds and ends of the regular scientific studies, but something distinctively different — a course in which English studies should enter as a solid and disciplinary part of the student's training. The number of students in this department is now sufficient to form a class — the instruction of Prof. Howison leaves nothing to be desired in the department of logic, and this year will give us additional facilities for thorough instruction in modern languages and a favorable opportunity seems offered for arranging a course of study of a less technical character than that of the chemist, architect, or engineer, in which foreign living languages, the English language and its literature, civil history, the elements of municipal, as well as constitutional law, physical, political and economical geography, and other studies which go to form the future man of business, shall take the place of that portion of the higher mathematics and purely professional scientific training which such students would omit. It will be for the Government of the Institute to say whether such an enterprise shall be undertaken. A strong argument in its favor must always be, that a valuable *systematic* course of study might thus be provided for a large number of students who, through want of scientific preparation, or inaptitude for higher mathematical studies, at present either drop into all kinds of miscellaneous specialties, or drop out of the school altogether. For a good many years to come it seems likely that a large number of students will continue to enter our school who are either unable to compete for our strictly scientific degrees, or do not desire to take them, and it seems

highly desirable that something more systematic should be provided for them than our frequent "special" and "partial" courses. It would be altogether undesirable that the high standard at present set for the attainment of our purely scientific degrees should be lowered in order to meet the wants of students unapt or disinclined to higher scientific studies. I think it is not too much to say that for these students the Institute has already at its command the materials for forming a parallel course of study, equal in disciplinary value and in practical usefulness to the strictly scientific courses which are now so thoroughly carried out.

I must again respectfully represent to the Government that the wants of the English department are great in every direction. It needs a lecture room of its own, equipped with proper accommodations for writing, and with facilities for the exhibition of maps and other apparatus, and in immediate connexion with a larger and better-appointed reading-room. In the reading-room it needs a larger collection of well-selected books of reference. In addition to books of reference, it is very much to be desired that it should have a selection at least of the best works of standard English and American writers.

All which is respectfully submitted,

W. P. ATKINSON,

Professor of English and History.

REPORT OF AN EXCURSION MADE IN THE VACATION OF 1872–73.

In the summer of 1872, a party of twelve students, under my charge and that of Instructor Hoyt, visited some of the principal bridges of the country, and other works of interest to engineers. The party went first to Albany, to inspect the bridge over the Hudson; thence to Philadelphia, where the Baldwin Locomotive Works were visited; thence to the bridge and iron works at Phœnixville, where, by the kindness of Mr. Coffin, the various steps in the manufacture of iron bridges, beginning with the ore, were observed, and much valuable information gained; thence to Pottsville, to visit the coal region and the steep gradients on the Broad Mountain tracks; thence to the railroad shops at Reading, where Mr. Paxon, the master machinist, conducted the party through the works and pointed out many interesting processes in the manufacture of engines and cars; thence to the Bessemer Steel Works near Harrisburg, where Mr. Felton, the President of the company, gave the party an opportunity of seeing the whole process of manufacturing steel; thence to Pittsburgh, where the Keystone Bridge Works were visited under the guidance of Mr. Linville, and the various parts of the great steel arches of the St. Louis bridge over the Mississippi were seen; thence to the Oil Regions, by the Alleghany Valley Railroad, as far as Peters-

burg; thence to Cincinnati, where the new railroad bridge and the suspension bridge were the principal objects of interest; thence to Louisville, where the bridge over the Ohio, and the canal around the falls, and the Louisville Bridge Company's works were visited — these last under the guidance of the company's engineers, Messrs. Vaughan and Trafton; thence over the Louisville and Nashville Railroad as far as Cave City, to see the bridges on the line and to visit Mammoth Cave; thence to St. Louis, where the abutments and piers of the great bridge over the Mississippi and the Water Works were visited.

At St. Louis the students were divided into six parties, and to each party was assigned one of the principal bridges, which was to be visited and studied in all its details, with a view of giving a full description of the work, accompanied with accurate drawings. The party was, in effect, here broken up, as its members had generally to return by different routes, in order to study the works assigned to them. This report should not close without a grateful acknowledgement of the courtesies so generally shown to the party by the railroad companies, and by the engineers, master machinists, and others connected with the establishments visited.

JOHN B. HENCK,

Prof. of Civil and Topographical Engineering.

PROFESSOR ORDWAY'S REPORT ON THE VACATION EXCURSION OF 1873.

President Runkle:—

DEAR SIR: — Visits to manufactories and metallurgical works have always proved a most important adjunct to the instruction given by us in Chemical Technology, and I am happy to say that the past year has witnessed no diminution in the number and variety of these excursions. It is very pleasant to find so much liberality as we have experienced on the part of gentlemen in charge of establishments not generally open to visitors, and to learn that our manufacturers take so much interest in the work and objects of the Institute.

In the department of Mining and Metallurgy it is a part of our plan to give students opportunities for more extended and continuous attention to actual mining, ore-dressing, and smelting operations, than the regular course of study in term time admits. In accordance with this idea, a long planned expedition to the Adirondac iron region has been successfully carried out since the close of the school year.

Arrangements were made for a party of nine students, together with Prof. Richards and myself, and on the morning of June 24th we met at the Lowell depot, arrayed in garments

suitable for rough usage, each furnished with note-books, hammer and haversack, blanket and poncho, and the minimum of baggage required for a three weeks' tour. Our first destination was Warren, N. H., where we spent the afternoon in visiting the lead and zinc mine, which has been worked, at intervals, for many years. The present happens to be a stand-still period, and as the underground part of the mine was filled with water, we had to be content with examining the extensive open cut and the large piles of zinc ore at the surface. Still there is much to be learned there, and we were amply repaid for our three mile' walk. The next day we proceeded by rail to North Lisbon, on foot to Franconia Village, and then by wagon to Franconia Notch, and back to Lisbon. At Franconia we devoted some time to the old charcoal iron furnace, which is in pretty good condition, though it has not been in blast since 1859. The fact is, Franconia is not now favorably situated with respect to fuel, as wood is too scarce to supply an iron furnace many years, and the village is too far inland to allow the use of anthracite. We were shown good specimens of copper ore which has lately been found in the town, but had not time to visit the opening from which it came. We reached Lisbon at a late hour, but were up betimes the next day, and improved the morning hours in visiting the stamp mills originally built for treating the gold bearing quartz of a mine about two miles north of the village. The machinery was afterwards run to powder a rock from Lyman, which was in great demand not long ago, on account of its supposed virtues as a fertilizer, and lately Dr. Ray, whom some of us met two years ago in Colorado, has reopened the gold mine, and is using the mill for extracting the precious metal by a peculiar process of amalgamation. Dr. Ray reports the quartz as containing $35 worth of gold to the ton of rock, and at this rate the mine should pay, if the separation of the gold is properly conducted. It seems to us that chlorination is the proper method of treatment.

Lisbon was not included in the route originally laid out, and

it was not thought best to tarry for the sake of visiting the mine. So at half past eight we were in the cars bound for Ely, Vt.; and at one o'clock, after a short stage ride, we found ourselves at West Fairlee. After securing quarters and disposing of a very acceptable dinner, we walked on a mile and a half to the adjacent town of Vershire, and made a preliminary examination of the extensive copper mine and smelting works of the Vermont Copper Mining Co. This reconnoissance enabled the professors to make, in the evening, a systematic allotment of parts for the morrow, so that each student should be responsible for the full and exact observation of some particular branch of the work, besides gaining a general knowledge of the whole. By the kindness of Messrs. Daniel and William Long, the skilful gentlemen in charge of the establishment, and of Mr. Ely, the President of the Company, every thing was opened to our inspection, and we are indebted to them for devoting much of their time to us during our stay at Vershire and West Fairlee. The next day we crowded into an ore car, and with crouched heads, rode into the horizontal adit nine hundred feet, and then, in company with Capt. Pascoe, explored the mine below and above, coming out into the hot summer air at a point high up the hill. The captain also conducted us into a lower horizontal drift, which is being carried forward rapidly with the aid of the Burleigh drill to intercept the deeper parts of the workings. After a needful lunch the afternoon was devoted to a close study of the picking, washing, and smelting operations. We had hardly expected to find in New England a copper mine turning out nine hundred tons of picked ore per month, and it was to be regretted that so little time had been allotted to this rich mineral region. Two weeks might well be given to the copper mines of Vershire and the adjoining towns, Corinth and Strafford, together with the unworked lead mines of the neighboring town of Thetford.

Saturday morning a conveyance was procured for ourselves and baggage to the railroad at Sharon, and, while the horses were resting at noon, we made a somewhat hurried detour on

foot to the copperas works and copper mine at Strafford. The manufacture of sulphate of iron was in full operation, but the mining was suspended for the time being. Night found us at Burlington, ready to enjoy a Sabbath of rest. The great lumber interests of Burlington did not immediately concern us, but before the arrival of the steamer on Monday most of the party took occasion to visit the pleasant grounds of the University of Vermont. A strong wind somewhat delayed the passage of the boat southward, but we arrived at Port Henry in season for dinner. Thus in somewhat less than seven days we reached the chief point for which we started. Here centres the present iron interest of the Adirondac region, and here are to be seen the sources of the ore which is shipped to all parts of the country. Commencing work at once, we called on Mr. Foote, the obliging Superintendent of the Bay State Iron Co.'s furnaces, and were soon engaged in studying the smelting of magnetic iron ore, with anthracite coal, in furnaces of the most approved construction. These two high furnaces turn out over fifty tons of pig iron in twenty-four hours. A little more than half a mile south, the Cedar Point Iron Co. are building a new furnace, for which Whitwell's regenerative stove will be used. Mr. Witherbee, the Superintendent, is the first in the United States to adopt this blast heater, and this is the first anthracite furnace in which the recent invention is to be tried. Walking down to Cedar Point in the evening, we had a good chance to see the great number of elementary parts which enter into the making up of the iron smelting works of the present time.

Tuesday was devoted chiefly to the examination of the famous Cheever ore beds, a mile and a half north of Port Henry furnaces. In the forenoon we went by a long stairway, down a steep incline, into the middle bed, which has an average thickness of some six feet, and is of unknown extent. After the dinner hour we were lowered in the iron bucket, half at a time, down the perpendicular shaft three hundred and twenty-five feet in depth, to the lower bed. This vein of clear, solid magnetic ore is from five to fifteen feet thick, and the

working has extended over many acres underground. There was ice in the bottom, and the air of the mine stood at 38° F. After travelling about a long distance in this atmosphere, and coming up one of the inclined shafts, by an almost interminable stairway, into the open air of a hot July day, we found the contrast more striking than agreeable. Any farther vigorous effort was not felt to be desirable, but due attention was given to the inclined railway by which the picked ore descends three-fourths of a mile to Lake Champlain, drawing back the empty cars or coal to run the engines for hoisting and pumping. Three rails are here made to do the duty of four, by having a really double track where the ascending and descending cars meet each other. Wednesday was spent in a closer study of the blast furnaces with all their appurtenances, and a pleasant evening row on the lake to the old fort at Crown Point closed our explorations from Port Henry as a base. Early next morning we proceeded, with all our baggage, to Mineville, seven miles distant, over the Lake Champlain and Moriah Railroad,—a road built solely for transporting ore, and very remarkable for making an ascent of thirteen hundred feet in going the seven miles. About thirteen hundred tons of ore per day are taken from the immense deposits among the hills, over this road to the Lake, to be carried thence by canal boats or cars to all parts of the country. Under the guidance of Mr. Roe, Superintendent of the Port Henry Iron Co.'s mines, we were lowered down an open cut into a bed a hundred feet thick, and how much more is not yet known. Here is mining indeed, or it might almost as well be called quarrying. With so vast a vertical face exposed, the horizontal progress is slow, and the underground working is as yet of moderate extent. There was ice in the lower part of the open cut. It is said to be too cold to work in winter at the bottom of the mine, and the workmen are then kept on higher levels. After traversing the underground openings we ascended by ladders. The hoisting machinery at this mine is of admirable construction, and the power for pumping is transmitted from the engine house

down into the shaft by wire ropes like the ropes used for hoisting.

Near by is the old Sanford ore bed, in which the magnetite was at first found largely mixed with apatite, and was therefore of little value, though a preposterous scheme was set on foot to work this vein for the sake of the phosphate of lime, which was cleansed by means of magnets and made into a fertilizer. It did not pay; but it is found that the ore improves as the vein runs deeper, and work has been resumed in the Sanford bed by Witherbee, Sherman & Co. During the noon hour we went to the New Ore bed half a mile off,—a bed remarkable for yielding very large crystals of magnetite. Three of us descended some nine hundred feet, by the inclined stairway, to the heading, where a few men are kept at work. The ore needs some picking, and it has to be carted to the railroad, so that the cost is enhanced, but it is in demand on account of its purity. The Barton bed, high up the hill, crops out in many places for a distance of half a mile, and in years past has been worked by several openings. Most of the excavations are abandoned and full of water, but the Bay State Co. are still smelting some of this ore. While a heavy shower was clearing up, we found time to dispose of the ample dinner which had been made ready for us. In the latter part of the day we visited the charcoal blast furnace of Witherbee, Sherman & Co., about two miles away. This is an old furnace remodelled and modernized, and it presents some notable peculiarities. Everything is well arranged and the work is conducted with skill. The charcoal is made in a set of rectangular kilns close by the furnace. The ore is carted from a distance. From the increasing scarcety of wood, this furnace must in a few years be numbered among the things that were.

The growth of Mineville has been rapid, and there is little house room to spare. We had therefore to bring our blankets into requisition, in sleeping on the floor of some unfinished rooms in a new house. The hard pine mattress proved no hindrance to sleep, and the morning of July 4th found us well

rested and ready to move onward, a patriotic relaxation from work being deferred till the next week. It was not easy to procure conveyance on the national holiday, but at length we proceeded by wagon to New Russia to study the bloomery forge there. Work was suspended, but there was all the better chance to examine the apparatus that pertains to this American improvement on the oldest and simplest method of making tough iron. In the establishment at New Russia there are four forges, each capable of turning out three hundred pouuds of blooms every three hours. We were busily occupied an hour or two in noting the roasting stacks, stamps, elevator, jiggers, blower, heating pipes, forges, cranes, trip-hammer, steam boilers, and engine, — each one giving special heed to his assigned details, and subjecting the good-humored workmen to a thorough catechizing. Another ride of some miles brought us to Elizabethtown in good season. After tea there was still enough daylight left to allow us to look into a well appointed bloomery, not now in blast, which showed some modifications not seen at New Russia.

It was now unanimously decided to make a diverson to Tahawus, or Mt. Marcy, in the wilderness. So on Saturday, leaving all superfluous baggage at Elizabethtown, we secured a wagon to take us to the head of Keene Flats, on the Ausable River. And here, tormented by myriads of black flies, but having comfortable rooms and plenty to eat, we spent a quiet Sunday. There is no morning service at Keene Flats, and it seemed not inconsistent with the proper observance of the day to take a walk of a mile and a half into the woods, and view a most romantic waterfall. The crumbling away of a thin trap dyke has here made a gap in the high, precipitous rock, and through this channel a little stream from the Giant of the Valley falls down a hundred feet or more. Farther up the stream occurs another pretty fall of perhaps twenty-five feet. In the afternoon, all who chose rode with our worthy landlady to attend divine service in the little red school house at the Flats.

They told us that the ascent of Tahawus usually takes three

days,— the guides are paid by the day,— but we determined, if possible, to spend the night of Tuesday in Elizabethtown. Rising therefore before daybreak, we got through our breakfast, took two days' rations in our haversacks, strapped on our blankets and ponchos, and began the march through the woods at five o'clock. The guide carried the fresh meat in his knapsack, a pail of butter and a hatchet in his hand, and the heavier part of a hundred pound skiff on his shoulders. Four miles and a half of an up hill and exceedingly rough road brought us to the lower Ausable Lake. Here, borrowing a second skiff, we all embarked, with cautious balancing, for a two mile row over a smooth sheet of water, surrounded by scenery of the most imposing grandeur, the like of which is hardly to be found in the wildest parts of New England. The skiffs were left turned upside down on the farther shore, and then another walk of a mile and a half along the stream brought us to the outlet of the upper Ausable Lake. Making smudges, which hardly checked the savage voracity of the flies and mosquitoes, we waited impatiently till the guide had gone to a hut a mile beyond for his gridiron, kettle, and frying pan. Those who had a chance for a fair fight could make out to endure entomological trials; but the one who undertook to find the boiling point of water with the hypsometer when a thousand insects were maliciously waiting to pounce on him at the critical moment of observing the thermometer, did not consider it a pleasant experiment. At length, girding ourselves for a climb over Bartlett Mountain, we had a a chance during the next two hours to test pretty fully the strength of our lungs, ankles, and knees. The four mile tramp to Camp Marcy, by a faint trail leading over mossy stones, tangled roots, and prostrate trees, with our food and blankets to carry, was very much like hard work, but as this was our holiday sport, we tried to make light of it, though with indifferent success. In due time we joyfully greeted the camp, which consisted of some crotched uprights with cross poles that supported one end of some large slabs of arbor vitæ bark, the other ends resting on the ground. Here was a brook o clear

cold water supplied by the Haystack. Here we washed and lunched. Here we piled our packs on the ground and covered them with a large slab of freshly peeled bark. Then, with a few hammers and other slight encumbrances, we were off for the final ascent. From Camp Marcy to the top of Tahawus is hardly a mile, but the rarity of the air was increasing, breathing did not go on unconsciously, and frequent halts were needful, to allow the adjustment of the system to outward circumstances. Still, as compared with the previous march under burdens, the climb was easy and rapid, and at half past four o'clock we were on the highest spot in New York. The thermometer stood at 60° F. Water boiled at 202.5° F.

Who would be so rash as to attempt a description of the soul-expanding scene which here delighted our eyes for an hour and a half, and which will remain in memory a joy forever? Farther on, in the solitary depths of the unlimited forest, lay the Saranac Lakes, invitingly spread out, and the whole view called up for the time each one's latent love of a roving life — but Tahawus was to be the remotest point of our journey. Lake Champlain in the remote distance suggested thoughts of home, and the declining sun recalled the consciousness that the way back to camp could be followed only by daylight. So in jubilant mood we commenced the return by walking, sliding, running, scrambling, leaping on bare rocks and mossy banks, through groves of old fir trees scarcely two feet high, through shallow streams, peat basins, tangled brush, and slippery earth, down the half clad mountain side. Arrived back at the lodging place, the guide, with some help, made a large fire to light up the camp and get ready the supper of broiled mutton, fried mutton, fresh bread, toasted bread, and tea without milk. A few more tender members of the party chose the well ventilated bark shelter and lay rolled in blankets with feet to the fire. The rest, like the guide, scorning luxurious indulgence, spread their ponchos in the open air. A midnight tour of inspection showed the outsiders to be all in the cool enjoyment of a noiseless oblivion, but, somehow, at dawn of day, two or

three were found to have yielded to the attraction of the central fire. At 5.30 A.M., July 8th, the thermometer stood at 42° F. All were up bright and fresh, and with appetites keen for a breakfast with the same sumptuous bill of fare as we had nine hours before. We left Camp Marcy with very light haversacks, but Bartlett Mountain was no tamer than the day before. Near the outlet of the lower Ausable pond we were conducted round to the Rainbow Fall, which comprises several high, slender cataracts of wondrous beauty and wildness. Then it began to rain, and ponchos came in use. After the remaining four mile walk through the wet woods, we arrived back at Mrs. Beede's in a forlorn looking condition, but with merry hearts. After a dinner of civilized life, the wagon in waiting took us back to Elizabethtown. The next day a pleasant ride of eight miles brought us to Westport, with time enough before the arrival of the southward bound steamboat to allow full inspection of an unsuccessful manufactory of steel from iron sponge. This inoperative show of wasted money was well worth seeing, as a palpable illustration of one of those often invented plausibilities which find ready endorsement among men of some experience who ought to know better; and which captivate monied men who are ready to believe that in a new business the ordinary laws of profit and loss do not hold. A charcoal iron furnace, long out of blast, is to be seen on the north side of the bay of Westport, but it did not seem likely to reward us for a long walk that way.

At noon the steamer hove in sight, and we were soon on the way to Ticonderoga. In taking the four mile stage ride from the landing to the higher level of Lake George, we unexpectedly passed a new bloomery forge in full blast, and much regretted that there was not a spare day to allot to this and the iron and plumbago mines on the mountain near by. From the deck of the steamer on Lake George, could be seen the four large circular charcoal kilns which supply fuel for the bloomery. Situated on the lake shore, at the outlet, they are each provided with an inclined track for hauling the floated wood up out

of the water to the top of the kiln. The mountains surrounding Lake George are well wooded, and ought always to be kept so. The lake affords easy transport to the kilns. Hence to the forge is an easy, down hill road, and the falls furnish water for all the needed machinery; so Ticonderoga is a most admirable location for this branch of the iron business. It seems strange, that with all the study and skill that have been brought to bear on the iron manufacture, the best iron should still be economically made by the bloomery forge, which is but a slight modification of the primitive apparatus used centuries ago. But bloomeries are by no means out of date yet. The afternoon sail over the length of Lake George combined recuperative rest with calm, positive enjoyment, and it came in at just the right time of the week to suit our needs. The next morning, instead of waiting at Caldwell for the regular stage, we chartered an ample express wagon to take us earlier to Glen's Falls, so as to have time to see the falls, the limestone formation, the very large saw mills, the paper mill, the marble saws, and some of the many perpetual lime kilns of the Jointa Lime Co. These kilns turn out, from the black stone quarried close at hand, about one hundred and twenty barrels each of very white lime every twenty-four hours, being fired with slabs from the saw mills at the falls. The kilns and store-houses are built all along the canal, so that the chance for shipment is the very best.

Taking the cars a little after eleven o'clock, we arrived in Saratoga at noon, and there stopped over one train to view the Springs, and make a physiological test of the various waters. No positive results, except a few wry faces, followed these deep and frequent potations. After our arrival at Troy, there was still daylight enough left for a visit to Cohoes Falls. At nine o'clock we went to the Bessemer Steel Works, below Troy, to see a "blow" by night. The complete working of one conversion and the beginning of another, finished out for us this long day of sight seeing. The sun had been some time above the horizon when we began work the next forenoon. A due

regard to our financial resources suggested the propriety of a short stay in the city, and West Stockbridge was decided on as our next sleeping place. So the forenoon was spent in a close study of the Bessemer Works, and the rest of the time, before a late dinner, was mostly devoted to the two blast furnaces of the Rensalaer Iron Works, in which they melt a mixture of red hematite from Rome, N. Y., magnetic ore from the Adirondac region, and brown hematite from down the Hudson, with anthracite from Pennsylvania.

Journeying on to Albany, and from Albany to State Line, we sent forward the commissary committee, in a hired wagon with the baggage, to look out for quarters at West Stockbridge. The committee were happily surprised to learn that, in anticipation of our coming, free accommodations for our whole party had been provided through the generous hospitality of Edward L. Baker, Esq., President of the West Stockbridge Iron Co. We were by no means loth to acquiesce in the arrangement, for Sunday was coming, and what could be better than to have a day of rest among the Berkshire hills? Saturday morning Mr. Bliss, agent of the West Stockbridge Iron Co., was ready to go with us wherever we desired. Making suitable provision for the repair of wasted muscle, we proceeded first to the Leete Ore Bed, a large deposit of carbonate of iron and brown hematite, about a mile and a half from the village. Here we viewed the open workings, and then lighting our candles we went down the shaft and took a long tramp in the several levels underground.

As the Hudson Co.'s extensively worked bed on the other side of the road is but a continuation of the same vein, it did not seem worth the while to go below the surface again, but making an inspection of the upper works, we returned to the weigh-house of the Leete bed, and attended to our midday meal. Taking a look at the rude, but effective, apparatus used for washing dirt from the ore with the water pumped up out of the mine, we went on to the Richmond furnace. Here we found a single blast furnace, in a convenient situation,

together with two round, and four rather odd-looking, conical kilns for making charcoal, and an excellent arrangement of revolving, perforated drums for washing ore. Everything is kept in the best of order, and there is a general appearance of deserved prosperity. The ore bed near by is worked by an open cut, but the mine is inferior to those in West Stockbridge, and most of the ore used at the furnace is brought from those beds. The return did not prove very tiresome, and after tea we took a short evening walk to Truesdell's lime kilns and the quarry from which the limestone is taken. Mr. Truesdell burns in perpetual kilns, with two side fires, using a mixture of wood and Cumberland coal. As the stone approaches white marble in purity, the lime is of excellent quality. A little farther on we came to the anthracite furnace of the Pomeroy Iron Co. in time to see the charge of molten iron tapped off. Night gave a favorable opportunity for seeing the gases burn in the air-heating stoves, and under the boilers.

A quiet rest over Sunday, which began for most of us after sunrise, prepared us for the labors of the coming week. But the heat of the weather on Monday was too intense to allow any very severe effort. We started immediately after breakfast to make a more thorough study of the anthracite furnace in the village. All the minerals collected since leaving Ticonderoga were packed and forwarded to Boston by express. A wagon was secured to take along our luggage and meet us at noon. We commenced the onward march by visiting an old abandoned manganese mine not far from the hotel. Two or three miles farther on is the Cooke bed, which was found, when formerly worked, to yield an ore too rich in phosphorous. But this mine is now being reopened by Mr. Can of New York, in hope of finding better ore lower down. The Steven's bed was next visited, though it has never been opened to any extent; but the ore crops out all along the brook, and this locality illustrates well what surface indications are. Another warm walk of a mile or so, brought us to the main point of interest, the Cheever Ore Bed; and here the wagon was waiting for us

with a welcome lunch. Refreshed by this, we put ourselves under the guidance of the captain of the mine, lighted our candles, and went down vertical ladders seventy feet to the fifth level.

A long walk in this, and another descent of thirty feet, brought us to the lowest of the seven levels. The bed is from four to eight feet thick, and is highly inclined. It is worked by a series of horizontal drifts extending many hundred feet each way from the hoisting shaft. There is a great deal of water to be pumped, and the working is so managed that the water all runs to a well in the lowest level, and is thence forced to the surface. The well will soon be carried down to a ninth level, and while the eighth and ninth drifts are worked, the upper ones will be in process of closing out. After getting some idea of the general character of the mine, and observing the operation of removing the pillars and closing out a level, we remounted by another shaft to the surface. Near by is the Old Hill Bed, which is worked by a very deep open cut. This is really a continuation of the Cheever, and, like that, yields a compact brown hematite of excellent quality. Nowise reluctant to take seats in the wagon, we rode on to the Andrus Bed, an abundant deposit of uncommonly compact ore, which shows at the surface of the ground, and is taken out by an open cut of moderate depth. Though the ore is very hard, and free from intermixture, it is so seamed that no blasting has hitherto been required. And now parting from our kind friend, Mr. Bliss, we resumed our ride, and were soon in Shaker Village, waiting for the cars. Two of us visited the Shaker Ore Bed, near the depot, and found only a large open cut now filled with water. It has not been worked for many years, but there is said to be a prospect of starting it again.

At length the train came along, and a short ride brought us to Pittsfield ready for tea, and a stroll about the town. Hoosac Tunnel was now the great point of attraction, and at a late hour in the evening we took the cars for North Adams, arriving at ten o'clock. Betimes next morning a commodious wagon, with

a stout team, was chartered for the day. Zigzagging up the western side of Hoosac Mountain, with a buoyant appreciation of the glorious prospect, and riding on a mile or two in the elevated valley, we found ourselves alongside the huge pile of stone which indicates the busy location of the central shaft. Without much ado we all entered the iron cage, with a guide, and descended one thousand and thirty feet in less than two minutes. Lighting candles we went on in water ankle deep to the heading, twelve hundred feet westward. When the noise of drilling, the outgushings of compressed air, the shouts of the miners, the dripping of water overhead, the continual foot bath, and the dodging of cars, ceased to be agreeable, we returned, and parting with our very civil guide at some distance east of the shaft bottom, picked our subterranean way, two miles and a half, to the eastern portal, over rough stones and smooth road, wet walking and dry paths, through narrow places and full sized portions, in lonely stretches and spots where busy workmen, with hard drill and powder, were trimming the ragged roof into a smooth arch, among standing cars and moving trains, through various strata of cool, warm, smoky, clear, almost stagnant air. Coming out again into the light of day, we turned into the ravine beside the eastern entrance, and climbed up to the romantic cascades at the confluence of two little streams falling from the mountain above. The next thing was to find the driver, who had gone on above ground to one of the hotels in Florida, and was supposed to have ordered our dinner. A meal of fried trout proved to be the result of this forethought. Riding up the eastern declivity of the mountain, across the depression, and down the panoramic western side, we went to the western shaft and inspected the air condensers and hoisting machinery, and viewed from a safe distance the nitroglycerine manufactory. Then a drive to the western portal and back to the hotel, finished out a well improved day. The evening was very pleasantly spent, by invitation, at the office of the State Engineer, Mr. Frost, who very kindly explained

the peculiarities of the nice underground surveying carried on in connection with the work of the Tunnel.

It was determined to spend the next night in Boston or at home, but by making an early start there would still be time, between two trains, for a visit to the emery mill and mine at Chester. Reluctantly passing by the charcoal iron furnace at Cheshire and the glass works at Berkshire, we reached Chester at ten o'clock. The factory happened to be stopped for lack of water, but there was nevertheless a good chance to see the Blake's crushers, the many sets of steel crushing rolls which need very frequent renewal, the sorting sieves, the washing tubs for removing the soft gangue rock, the driers, the dust floater, the continuous magnetic separators for taking out the iron ore, and the finished products, which are said to be turned out at the rate of three tons per day. Very near the mill is the vein of emery mixed with magnetic iron ore in a gangue of chlorite. It lies almost vertical, and it would be almost impossible to work it were it not for the intermixture of soft rock with the desired mineral. Some of us examined the horizontal drifts carried in at the base of the hill, and those just started higher up the steep hill side. Others improved the spare minutes in culling choice minerals from the rubbish heaps. The number of species found here makes this a delightful place for the mineralogist.

Wednesday evening at six o'clock we separated, to meet again on two subsequent days, for exchanging notes and squaring accounts.

Thus the expedition itself took twenty-three days, and the amount of money spent by each member of the party was about fifty-six dollars. This somewhat exceeded the estimated cost of the trip, but we rode more, and went farther, than was proposed at the outset, and it seemed to be felt by all that the time and money had been well and profitably spent. Work had been assigned to all singly and collectively, each being made in turn chairman of a committee of the whole with a definite subject to report upon. Every one had shown an earnest

disposition to make the most of the opportunities afforded. Perfect harmony prevailed throughout, and we may be sure that the nine young men who could be kept in close and constant intimacy for three weeks, without even a trifling discord, will always look back with unalloyed pleasure to the Adirondac Expedition of 1873.

To the Superintendents of several of the principal railroads in New England we are much indebted for favors in the way of transportation. Beyond these lines there was no way but to pay full fares.

The Professors who went are more than ever impressed with the proved value of such tours, and they would hope that something of the kind may hereafter be carried out every year. Then each student of Mining Engineering will have, during his connection with the Institute, two chances of becoming acquainted with actual mining and smelting. Our experience in this expedition suggests that it may be well to undertake less at a time, and make the time somewhat shorter. In going over much ground rapidly there is little chance to have a full discussion of one object while it is fresh in mind, before proceeding to another. Yearly journeys of moderate extent, rather than less frequent tours embracing a large circuit, seem likely to secure well digested ideas, and those shared by a larger number of students. By shunning expensive hotels and not being over nice about quarters, it may reasonably be expected that, aside from railroad and stage fares, the expenses for each individual could be kept within two dollars a day. This for a trip of fifteen or twenty days taken twice, does not make a large amount, and yet for some students it would be a serious addition to the regular expenses for instruction. We ought to have the means of assisting those in limited circumstances to go on the annual tour of observation.

The proper and timely development of the industrial resources of our country certainly can be insured only by having young men coming forward well trained to fill places where scientific skill is needed. And a little reflection will convince

every friend of sound education that there should be chances given for studying operations as they are carried on in real life. It is clear that no course of instruction can claim a reasonable degree of completeness which does not make provision for rendering the student's knowledge in some measure specific, and thus overcoming the not uncommon repulsion between theory and practice. May we not hope then, that at no distant day, we shall have a special fund yielding interest enough to lighten materially the outlay on the part of each individual, and thus render certain the continuance of these expeditions year by year?

Respectfully yours,

Sept. 2, 1873. JOHN M. ORDWAY.

REPORT UPON THE CHEMICAL LABORATORIES FOR THIRD AND FOURTH YEARS' STUDENTS.

To the President: —

Some improvements in apparatus have been made in the laboratories with a view to increasing the facilities for rapid and effective work; and at present nearly all the conveniences of this kind which are in use in the best schools in Europe, have been introduced, so far as the space and the arrangement of rooms devoted to the chemical department have allowed.

The thirty places in the third year's laboratory have been provided with Bunsen's filter-pumps, at an expense of less than thirty dollars, and it is believed that these contrivances will enable the student to perform a much larger number of analyses than heretofore during the time allotted to the chemical course.

In regard to the practical training of the students, two points have been kept in view.

In the first place, the course in general analysis has been made to cover as wide a field as possible, the analyses being chosen to illustrate general methods, applicable to a number of special cases, so that the experience might serve as a preparation for the ordinary work of an analytical chemist.

In the second place, those students who appeared to have

acquired the necessary skill in the routine work of the laboratory, have been encouraged to investigate unsolved problems in chemistry in order to give them an opportunity to educate their ingenuity, as well as their powers of observation.

The longest course of laboratory work pursued in this country scarcely gives a student sufficient experience to deal with original investigations advantageously, but still something has been accomplished in this direction, and four very creditable papers have been prepared this year for publication in a scientific journal.

Three of these are devoted to the investigation of analytical methods, and announce the discovery of new facts. A fourth deals with an important problem in general chemistry, namely, the direct formation of bodies of the petroleum oil class from their elements without the intervention of coal, or any organic matter, and also makes its contribution of new facts to science.

The professor of analytical chemistry has also prepared a paper for publication, and it is hoped that each year the contributions to chemical science from the Institute of Technology may not be wanting.

The course of study in the theory of chemistry has been carried on this year, as last, with the aid of a German textbook, and the class has acquired considerable familiarity with the language, as well as an acquaintance with chemical facts.

J. M. CRAFTS.

June 16, 1873.

REPORT ON THE INSTRUCTION IN THE DEPARTMENT OF MILITARY SCIENCE AND TACTICS.

To the President: —

In compliance with your request, I have the honor to submit the following brief report upon the instruction in my department during the short portion of the session in which it was under my direction.

Upon assuming charge of the military department in March, 1873, I found that the majority of the students looked upon the instruction as an unmeaning drudgery, and the time devoted to it as nearly wasted. It cannot be surprising, therefore, that comparatively little had been accomplished, and that discipline existed but in name. It has been my aim to impress the students with the idea that the military instruction is given to them, not for the purpose of making them soldiers, but that they may be more efficient citizens, that it is the duty of every citizen to make himself efficient to serve the country as a soldier in case of war, and that they should faithfully attend and receive the military instruction from a sense of duty and honor, rather than from a sense of obligation.

It must be remembered that a mere knowledge of drill is not all the military knowledge which is required to make an efficient officer. He should have a knowledge of discipline, and

the proper mode of maintaining and enforcing it; a knowledge of feeding, clothing, marching and encamping troops; the methods of procuring food, clothing, arms and ammunition, and the mode of preserving and accounting for public property. It was the lack of all this which caused us to lose a greater number of lives by disease, than by the bullet of the enemy, in our late war. The time now allotted to the military instruction is barely sufficient for imparting effective instruction in Infantry drill. The drill tends to improve the carriage of body and general physique of the students, therefore it should not be looked upon as a portion of their mental effort, and counted as such in regulating the mental burden of each student. It should rather be considered as a physical exercise, the tendency of which is mental relaxation. I am desirous of securing an additional hour per week, to be devoted to theoretical instruction in the method of organizing, disciplining and clothing troops; the care and responsibility of public property, and mode of acquiring and accounting for it; the duties in camp, on the march, and in the presence of the enemy, and the general principle of field fortifications, ordinance and gunnery. In short, I would wish to give such instruction as would enable the students to become efficient and capable Captains and Lieutenants of volunteers.

When I assumed charge, the corps of students was armed with muzzle-loading rifles, furnished by the State Government. They were partly uniformed, wearing an unlined blue flannel blouse and a naval cap, with the letters, M. I. T., embroidered thereon. The blouse is unshapely, and affords no protection from cold, being too thin even for under wear during winter. I respectfully recommend the adoption of a uniform of Chasseur cap, blouse and pants of Cadet gray cloth, trimmed with black. The blouse and pants may be procured at a cost of twenty-two dollars and twenty-five cents ($22.25), and are of such material and manufacture as to afford due protection from the weather, and are neat and serviceable as a uniform. From a personal consultation with the students of the present

second year class (then first year), I have ascertained that the feeling in favor of the adoption of a neat and serviceable uniform, such as I have mentioned, is nearly unanimous. If habitually worn by the students when not at drill (and I have reason to believe that many will do so), it will be an economy for them, as it costs much less for the uniform than for a suit of civilian clothes of the same quality of material and manufacture. I most earnestly request that the aforementioned uniform may be adopted, as it is desirable that the students should feel a pride in belonging to the Institute of Technology, and honored in wearing the uniform of its Cadet Corps. It will tend to develope interest in the instruction, and will be of material assistance in raising the tone of the department.

We have received from the U. S. Government for the use of the students, the following Arms and Equipments, viz.: — Two hundred (200) Cadet breech-loading rifles (same size as used at West point); one hundred and fifty (150) sets Infantry equipments; twenty-seven (27) non-commissioned officers' swords, and twenty-seven (27) non-commissioned officers' belts.

Two (2) light six (6) pounders and carriages.

Two (2) cassions and equipments for a section of Light Artillery.

Eight (8) signal kits (complete), including staffs, flags, torches, shades, extinguishers, nippers, wormers, scissors, funnels, canteens, lamp-wicking, matches, and haversacks.

Four (4) telescopes.

Four (4) marine glasses (binocular).

Four (4) manuals of signals.

Two hundred (200) signal code cards.

I respectfully call attention to the necessity of a hall or building in the immediate vicinity of the Institute to be used for drill, and as an armory. Much valuable time is now lost in going to, and coming from, the present hall. A hall or building suitable for this purpose may also be used as a gymnasium. In this connection I may be pardoned for adverting to the importance of introducing a system of obligatory daily gymnastic

exercises in conjunction with the military department. It is neither necessary nor desirable that the students should be made gymnasts, but simply that they should be required to go through a series of daily exercises under the supervision of a physician, or other competent person. The exercises should be comparatively light, and of such a nature as to preclude the possibility of even the weakest student being injured thereby.

The discipline of the Corps of Cadets has improved somewhat since the students have been made to understand that the Cadet officers would be fully supported in the execution of their duty, and that in rendering a prompt obedience to their officers they were not rendering it to the persons, students, but to the authority which they represent, *i. e.*, the Faculty. I have endeavored to establish and maintain, as nearly as the circumstances would admit, the discipline and routine observed in regular service. The trial of a student for "disobedience of orders," and "conduct unbecoming a gentleman," by a court martial composed of his fellow students, has had a beneficial effect upon the tone and discipline of the Corps of Cadets. The system of official correspondence and responsibility for public property involves some extra labor on the part of certain officers and non-commissioned officers. The ordnance and signal property are taken care of and accounted for by two Cadet officers ranking as Second Lieutenants. Other public property is taken care of, and issued upon proper requisition, previously approved by me, by the Quartermaster of the Corps. Invoices and receipts are regularly exchanged whenever public property is transferred. Monthly returns for property received and issued are required from Captains commanding companies, and other officers responsible for public property.

Each commissioned officer responsible for public property is assisted by a non-commissioned officer, who is of a junior class, and selected for his capability to succeed to the office for which he is thus serving an apprenticeship. The Adjutant attends to the duties usually attended to by Adjutants in regular service, *i. e.*, issuing orders, receiving reports and excuses, making de-

tails, and acting at all times as the official organ of the Commandant. He is assisted by a Sergeant-Major, who is selected from the first year's class, with the view of succeeding the Adjutant in the next year. The general rule which should be observed in the appointment and promotion of officers and non-commissioned officers should be, that officers and sergeants should be selected from the second year's class, and corporals from the first year's class. The selection of officers in the succeeding year should then be *first* made from the corporals of the preceding year. As the commissioned officers retain their positions but for a single year, it is a great burden to require them to purchase their swords and belts, and I therefore recommend that these articles be purchased by the Institute, and loaned to the officers, holding them responsible for any damage thereof, other than the ordinary wear and tear. In order to increase still more the dignity and importance of the officers and non-commissioned officers of the Corps of Cadets, and thereby increase the emulation, and inspire the discipline, it would be advisable to issue regular commissions and warrants, as also to enter their names in the printed catalogue of the Institute.

Respectfully submitted,

E. L. ZALINSKI,

1st Lieut., 5th U. S. Art'y.

REPORT UPON THE LOWELL COURSE OF PRACTICAL DESIGN.

On the 7th of October, 1872, the above course was commenced, with eight pupils, none of whom had any idea of the working of patterns, and all were unprepared to "trace" with pencil, or "outline" with the brush — two most important essentials in the work of designing.

The management of *colors* used for making patterns is also a very difficult matter with beginners. After a few weeks of trial, however, a rapid improvement was discovered, and the instructor was gratified to observe that the American youth of both sexes were easily taught, and were quick in comprehending and overcoming these difficulties. In November, the number of students had increased to thirteen, and after January, 1873, the number was twenty-five, all of whom exhibited a great interest in their work, and devoted themselves assiduously to its details. The first object to be attained in this department, or *atelier* of design, was a good execution, and all the energy of the instructor was devoted to this purpose — neatness in execution being a desideratum in designing. The course of study has been the same as that pursued in the *ateliers de dessin* in Paris. These ateliers are the nurseries of designers, who originate patterns for carpets, silks, robes, paper hangings, delaines, prints, etc., and sell them to all the manufacturers of

the world. In these ateliers there are apprentices, composers, and finishers, who produce from year to year, or from season to season, the most novel patterns. The apprentice prepares the colors, and begins to trace and paint patterns. After this, if sufficiently expert, he becomes a finisher, and the finisher completes the pattern which has been composed, and partially painted, by the composer. We believe that the success of the school is due in a great measure to the fact that we have strictly followed the above plan.

The bulk of the work accomplished by the students thus far has been in copying patterns, the few *original* designs executed by them being introductory to next year's work. No instruments are used except the dividers for making the "repeat" and correct distances, and a ruler for lines; all the other portions being strictly "free-hand drawing," and executed with the brush, in color, to give the patterns the same appearance as the calico, delaines, etc., when finished.

The hours of study are daily, from 9 A. M. to 5 P. M. The instructor in this department takes pleasure in stating that his pupils have all shown great application, and constantly increasing interest in their work, and he expresses highest confidence as to the success of making first class designers in this atelier, when so excellent a spirit is evinced among the students, and where so goodly a share of inventive genius is apparent among the American pupils — the girls as well as the boys.

Respectfully submitted,

CHARLES KASTNER.

June 2, 1873.

REPORT UPON THE INSTRUCTION IN PHYSICS IN THE COURSE OF LECTURES.

To the President: —

During the past year the facilities of the lecture-course in Physics have been largely increased in several ways. The printing of a portion of the notes which the classes were formerly obliged to copy from the blackboard, has greatly lessened the drudgery formerly attendant upon the earlier portions of the subject, and a marked improvement has consequently been noticed in the attainments of the classes, as shown by their various examinations, so that at the last annual examination fewer were conditioned in the Physics of the first and second years than has before been the case since the writer assumed the position of lecturer, while the average rank was at the same time proportionally higher.

Another partial change has largely contributed to bring about this desirable result. Instead of devoting half of the hour allotted to the exercise in oral questioning, a method which seems singularly ill-fitted for the thorough examinations of classes as large as those which we now have, the lecture is made to consume a somewhat greater proportion of the time than formerly. An interval of fifteen minutes after the beginning of the exercise is given, during which time the student may copy any

figures which are to be taken from the board, or call for a re-demonstration of any proposition or explanation of any difficult point, which may have suggested itself since the previous lecture. The knowledge of the class is tested by a series of informal written examinations held, on an average, once a fortnight, and usually occupying half an hour. These are substituted for the oral examinations formerly given before every lecture, and as the burden of examining carefully so large a number of papers is so great as to preclude the possibility of doing it so frequently, a portion of the papers — usually about a quarter of the whole number — are examined each time. This system has proved very successful in practice. In addition to this, occasional examinations are held, lasting for one hour. The ranks attained by each student at these times are registered in a book kept for the purpose, and together with the ranks attained at the regular annual and semi-annual examinations, form part of the records of the department.

The student is in no case required to prepare a lesson for recitation. The subject is fully discussed in a lecture, and the important points brought to notice. The first portion of the course, occupying the second half of the first year, is devoted to a thorough discussion of Mechanics, as it is only by a clear understanding of the fundamental principles of force and motion that the student can profitably pursue the latter part of the physical course. The lectures of the second year are devoted to the subjects of Sound, Light, Heat, Magnetism and Electricity. It is always the endeavor to combine the theoretical and the practical as far as possible; to teach the student what physical investigation really is, the care necessary to avoid errors, the corrections to be applied to observed results, and the perseverance without which no research of any value can be conducted. It is hoped that as the number of our students increases, it may be possible to establish additional series of lectures for those taking the course in Science and Literature.

While the mathematical demonstration of physical principles is given whenever practicable, the lectures are very fully illus-

trated by experiments. And as the success of the instruction in elementary physics depends very largely upon the number and quality of the instruments which we possess for the experimental illustration of the lectures, it will be advantageous to speak somewhat at length upon this subject.

It has been the custom of the writer to devote most of his spare time during the winter months of each year to the strengthening of some particular portion of his course of lectures. The principle followed is to plan the apparatus with special reference to the work of the Institute, and, whenever possible, to have it constructed in the building, or at least by workmen under immediate supervision. In this way the collection of apparatus has been largely increased at a comparatively slight expense. There are, however, certain large pieces of apparatus which cannot be constructed to advantage in this manner, and for which a specific appropriation outside of the regular amount allotted to the Physical Department will be needed, unless the necessity is obviated by individual generosity.

During the winter of 1872–73 the subject of Mechanics of Solids was worked up. The apparatus for illustrating this portion of physics was somewhat meagre, but there are now only a few additional pieces of apparatus necessary to render it quite complete. The collection comprises all the instruments necessary for the experimental verification of the laws of oblique and parallel forces, statical moments, centre of gravity, the mechanical powers, laws of motion, pendulum and friction. The subjects of elasticity, mechanics of liquids and mechanics of gases, are less completely illustrated, though the apparatus relating to them is sufficiently extensive for most present purposes.

The acoustic apparatus is exceedingly full, comprising almost all of the more important instruments made by Kœnig, of Paris, the first European constructor, together with many pieces of home manufacture. Besides the large collection presented to the Institute some years since by Mrs. Hemenway, the recent generous gift of Mr. J. C. Hoadley for this specific

purpose has enabled us to obtain from Paris a number of new instruments, among which the following are especially worthy of notice: —

Electric interrupter, with three tuning-forks, designed to keep up a continuous vibration by means of electricity.

Tuning-forks giving 256, 261, 264 double vibrations per second, respectively, being the middle C of the Physical, French and German pitch.

Set of ten steel cylinders, giving tones ranging from 4,096 to 32,768 double vibrations per second, for determining the upper limit of audibility in individual cases.

Kœnig's apparatus for measuring the velocity of sound within small distances; comprising an electric interrupter giving ten vibrations per second, a standard fork, furnished with a mirror, for the accurate adjustment of the interrupter by the optical method, and two electric sounders beating tenths of a second automatically under the influence of the interrupter.

Mach's apparatus for showing that the pitch of the note given by a sounding body is raised when the body is approaching the ear, and lowered when receding from it.

Harmonic flute for determining the velocity of sound in air or gas, by Wertheim's method.

Set of eight closed organ-pipes, comprising the gamut next above middle C.

Discs of brass for sympathetic vibrations of plates.

Apparatus of Count Schaffgotsch for studying singing flames, with whirling jet for repeating the experiment first suggested by Prof. Wm. B. Rogers, showing the alternate extinguishing and relighting of the flame.

Free reed and resonant tubes, for studying the laws of reed pipes.

Two organ-pipes having an interval of a fourth, giving their resultant tone when sounded together; also a large pipe in unison with this resultant tone.

Manometric gas-flame attachment to Kœnig's interference

apparatus, for studying the phenomena of interference of sound by means of the eye.

Crova's apparatus for illustrating by projection the various phenomena of wave motion. This apparatus is furnished with seven glass circular discs, upon which the necessary curves are traced, so that by their revolution before a vertical slit the movements of particles transmitting vibrations are illustrated, thus exhibiting the rationale of the progression of a sonorous wave reflection of an isolated wave, continuous reflection phenomena of organ-pipes, interference, etc.

Besides these the collection comprises several minor pieces of apparatus which have not been mentioned, and also a series of large tin tubes for exhibiting the phenomena of singing flames upon an extensive scale.

In this connection should also be mentioned a valuable set of pipes for illustrating the most important organ stops, presented by Messrs. E. and G. G. Hook and Hastings. The pipes are tuned to the same note, and comprise the Doppel Flute, Harmonic Flute, Flute, Trumpet, Hautboy, Vox Humana, Viola, Viol d'Amour, and other stops, which, together with the various sets of pipes previously belonging to the Institute, are amply sufficient for explaining the practical construction of the organ. It would be a desirable addition to our cabinet if we were to obtain specimens of other instruments used in the orchestra, of which we have several, although our collection is small.

The subject of optics is illustrated by means of the valuable collection of instruments purchased some years since by Prof. Rogers. There are, however, many deficiencies. The apparatus relating to heat is also in an unsatisfactory condition.

The department has received a gift of samples of a number of aniline dyes, for the study of their absorption spectra, from from Messrs. Rumpff & Lutz, of New York, through the kindness of their agents, Messrs. Wm. F. Freeman & Co., of this city.

The most defective portion of the apparatus designed for lecture-room use, is that relating to Electricity and Magnetism,

upon which a considerable sum must be spent in order to make it a fair representation of the present state of electrical science.

Taking into consideration those additional pieces of physical apparatus most needed in the course of lectures upon that subject, our most pressing needs are (1) a new and large air-pump of modern construction, (2) a powerful Ruhmkorff induction coil, (3) an electro-magnet of considerable size, suitable for exhibiting the phenomena of diamagnetism, (4) some form of chronograph. There are constant embarrassments resulting from the absence of these almost indispensable instruments, and it is hoped that some means may be found to remove the deficiency before long, so that the department may be enabled to bring its apparatus to that state of completeness which should characterize the collection of the Institute.

It is also desirable that before the beginning of another year the subject of Photography may receive a more systematic treatment than hitherto. The following is presented as a brief outline of a suitable course.

Introductory lectures, treating of the history of photography, résumé of the chemical and physical principles involved, sketch of the optical portions of photographic apparatus, forms of portrait and other objectives, and preparation of reagents; methods of taking negatives on collodion, both wet and dry, methods of taking positives on collodion, paper, etc.; processes of photographing microscopic and telescopic objects. In addition to these topics the lectures should treat of of carbon-photographs and the modern photo-mechanical processes, the Albertype, Heliotype, and Woodburytype. The department is already in possession of an extensive illustrative collection of prints by these methods, and our thanks are due to Messrs. J. R. Osgood & Co. and the "New England Photo-Plate Printing Co." of Boston, Mr. Rockwood, of New York, and the "American Photo-Relief Co." of Philadelphia, for aid in forming it.

The subject thus discussed should at the same time be taught practically by requiring students to take negatives from appara-

tus, prints, buildings, and other objects, and to make from these positives on both paper and glass. If possible in the time allotted, the dry methods should also be taught. In addition to this, special students in physics should acquire the ability to execute negatives from microscopic objects, and regular students in certain courses might be required to furnish specimens of their work before being graduated by the Institute. If the necessary apparatus could be supplied shortly there is no reason why such a course should not be opened regularly at the beginning of the next school year.

Finally, it should be kept in mind that while our apparatus was never before in so good condition as at present, yet additions are necessary every year in order to keep pace with the advance of science.

All of which is respectfully submitted.

CHARLES R. CROSS,
Assistant Prof. of Physics.

MINING AND METALLURGICAL LABORATORIES.

President J. D. Runkle.

DEAR SIR: —The purpose of these laboratories is to furnish the means of studying experimentally the various processes of ore-dressing and smelting. Ore may here be subjected to the same treatment, and by the same kind of machinery and other appliances as are in use at the best mines and metallurgical works in this and other countries.

This may at first appear to be a strong statement, as such a laboratory might be made to cover acres of ground, and to cost thousands of dollars, if we were to include all the demands made by the immense iron interest of the day. But when viewed from the position which the Institute assumes towards these laboratories, it will be seen to be not only possible but practicable to build and to carry on such an enterprise.

Our aim is to have one representative machine of each class. Thus one automatic hydraulic jigger will serve to illustrate all automatic jiggers used in this country, and abroad, and when this is thoroughly comprehended, the student will be able readily to understand all others. In like manner, one kind of reverberatory furnace for roasting gold and copper ores will, for the present, be made to represent all kinds. Practical instruction in the elements of the subject is to be sought for, rather than the scientific completeness which can only be acquired by following closely all the details in some large smelting establishment. And of course we have neither the time nor the means for imparting all the niceties of every special branch.

In systematizing this department there have been many unavoidable delays, and many difficulties to overcome, some of which will be presently mentioned; but it is fully expected that the laboratory will be in thorough working order for the use of the class in mining during the year 1873–74.

The mining laboratory has, at present, in successful operation, some of the most approved ore-dressing and mill machinery now in use in California and Nevada, for gold and silver ores; consisting of a Blake crusher, a five stamp battery, an amalgamating pan, a separator and concentrator, complete in every respect, and capable of treating half a ton of ore in a day of ten hours; the arrangement of these machines is shown in the accompanying cut. The laboratory also contains a hydraulic-jigger, a Rittinger shaking table, a Whelpley and Storer pulverizer, and a Sturtevant fan-blower; all of which, with the exception of the jigger, are shown in the cut.

New machines and furnaces will be from time to time added, as occasion requires.

The metallurgical laboratory contains (*a*) a cupelling furnace, arranged upon the German plan, capable of cupelling fifty pounds of lead at a time; (*b*), a blast furnace capable of smelting five hundred pounds of copper ore in a day of ten hours, having a cross section of twelve by eighteen inches, and one tuyere in the rear; (*c*), (*d*), roasting and smelting reverberatory furnaces; (*l*), (*l*), (*l*), a forge, anvil, and bellows; (*f*), (*g*), (*h*), (*i*), crucible and muffle assay furnaces; (*k*), a large kettle, which may be used for smelting lead (Parkes' process), or as a large sand bath for chemical purposes. The coal bins are placed under the large mortar.

The experimental work of this laboratory is carried on by the students under the immediate supervision of the professor. When a class of students begins work in the laboratory, each is assigned a sufficient quantity of ore to work upon. He first determines the minerals contained in the ore, samples it, ascertains its value and character by analyses and assays, and makes such other preliminary examinations as may serve to indicate in

a general way the [illegible] to work on the [illegible] according to the [illegible] ore. [illegible] also takes account of the [illegible] and chemical [illegible]

[illegible]

Now it is evident that in starting a new [illegible] details must be [illegible] of a proper course in practical [illegible] during the past year has been [illegible] trying to discover the best way to [illegible] found that a student, when [illegible] accomplish but little in the way of making accurate and useful results; for such operations require very much more time than any one would anticipate. Accordingly the following plan has been arranged for the coming year: — a student will receive an ore, examine and prepare it, but at the time when any machine or furnace work is to be done, he will have assistants from his own class, the work to be divided among the assistants, each attending to his assigned part, while the leader exercises a general supervision. At the end of the day each one must hand in a full and carefully written account of his work to the leader, who in turn prepares from these daily statements his final report for presentation to the professor.

By and by another student in turn becomes leader of a party, receiving a new ore to investigate, and so on until each one of the class has learned the duties of workman and superintendent, and the prescribed metallurgical course is ended. It is believed that in thus throwing the whole responsibility of a few simple things on each student, the work will be more thoroughly done, and the reports will be fuller and of far greater value. The student in charge, being free from all details of work, by constantly watching all his men, may be as confident of the correctness of his results as if he had performed all the work himself. The ores will be chosen for the

different students in such a manner that they may represent as large a variety of metallurgical work as possible.

There are no suitable text-books to be found to direct the student in this branch of his studies. "Percey's lead" has been at hand for consultation in respect to experiments on silver and lead. Watt's Dictionary and Kustel's processes of gold and silver extraction, are also used for reference; Plattner's Probirkunst has been used for gold gas-chlorination.

In fact, such is the state of the metallurgical literature, that a large number of expensive books are needed to cover what might be reduced to a tolerably small compass; for instance, the student does not want to know, when smelting lead by the reverberatory furnace, that nine different methods are in use in Germany and England. If at his first glimpse of the subject, he is brought face to face with nine different processes, all of which are nearly identical, he is confused, and fails to see why to choose one over another. He needs to know the principles and details of the processes which are most feasible for this laboratory; and hence, when suitable processes have been selected, it may be best to put them in book form and make a laboratory text expressly for this work. This can hardly be done without the experience of a year or two more.

In this report some reference should be made to the spirit with which students have taken hold of this work. The tone of feeling among them has shown that they have thoroughly appreciated the character, the use, and the demands of these laboratories. All work has been most cordially and carefully done, and it seems well nigh certain that when the resources of the laboratory are developed, which will undoubtedly be accomplished the coming year, the students will reap far more benefit from this course than was at first anticipated, when the difficulties were not only not overcome, but had not yet been discovered.

When preparing a young man for the possibility of filling responsible positions in after life, there seem to be three very important qualities to be developed in him; he needs scientific

attainments, capacity for organizing and directing work, and character or tone. Mere scientific attainments are to be derived more especially from books and lectures, while quick, ready judgment, inventive skill, self-reliance and directive power can be brought out only by practical work, such as the laboratories furnish. The character or tone developed in the student depends in no small degree on the influences around him. When the instructor joins heartily with students in their hard work, and contributes to its full success, the experience of the past warrants us in believing that an earnest, determined enthusiasm will be the prevailing spirit among them. Energetic, persevering effort is best induced by the living example of those who show the power of overcoming difficulties.

During the past year the old arrangement of studies, which was prepared before the laboratory was opened, has been continued; and as this allowed but one or two hours at a time for laboratory work, students have often been obliged to neglect lectures and recitations in order to finish an experiment which lasted a whole day. Thus irregularities were necessitated injurious alike to students and professors. For the coming year a new tabular view of studies has been arranged, which fully admits the demands for time made by metallurgical work. About four weeks during February or March, are set apart for continuous laboratory work, and during that time the student is to have no calls outside to distract his attention from a subject which requires his whole inventive power.

The want of an assistant has been very much felt while getting the work started. Too much manual labor was performed by the Professor while planning his work; he fully appreciates the impossibility of doing hand and head work together, and with this in mind the present system of class instruction has been planned.

An assistant has been appointed for the coming year, and it is hoped that with such aid much more will be accomplished than has hitherto been possible.

A few examples of the work performed during the past year are here cited: —

ILLINOIS LODE, CENTRAL CITY, COLORADO, BY GEORGE PHILLIPPS.

This is essentially an argentiferous gold ore, containing sufficient copper to be worth saving, and a considerable percentage of arsenic and antimony.

The ore was found to contain the following minerals: —

Gold bearing minerals: — Pyrites, gray copper, copper pyrites, zinc blende, galena, and a loose, black substance, which contained copper, sulphur, iron and arsenic, and seemed to be the result of decomposition of gray copper.

Gangue or vein stuff: — Quartz, feldspar, pyrites in grains, carbonate of iron in small crystals.

The ore was easily separated by hand into three lots, gray copper, pyrites, and dust. After being finely pulverized, the whole was roasted, with the exception of 15 lbs. of pyrites. The total weight was 68 lbs., containing 4.7414 grams of gold and 16.305 grams of silver. The pulverized ore was then mixed with coal dust and iron ore and smelted for matt. This matt was again pulverized, roasted and treated with sulphuric acid, which removed the copper as sulphate The copper was precipitated by iron, and then dried and fused in a crucible. This copper was all lost by an accidental crack in the crucible. Some of the silver was undoubtedly carried with the copper as sulphate.

The residue from sulphuric acid was melted with oxide of lead and a little sand, yielding 8 lbs. 7 ozs. of lead carrying silver and gold. This lead, when cupelled, yielded 2.38 grams of gold and 9.40 grams of silver, which were separated from each other by nitric acid. It will be seen that nearly half the gold and silver originally recognized in the ore by assay, were lost in the final result. This loss has not been satisfactorily accounted for, from the hasty manner in which the work was done.

COPPER ORE. LAST CHANCE LODE, RAILROAD MINING DISTRICT, NEVADA.

This ore was presented by Mr. J. W. Revere, who superintended the metallurgical work himself.

The ore contained red oxide of copper (cuprite), red oxide of iron (hematite), silicate of zinc (calamine), and a little galena, and also a small percentage of silver.

Two partial analyses were made of a sample of the ore, by Miss E. H. Swallow.

	No. 1.	No. 2.
SiO_2	8.37	8.43
Cu	19.87	20.44
Fe_2O_3	35.50	34.10
	63.74	62.97

The ore, amounting to 656 lbs., was treated in the blast furnace, and with it was used from time to time old copper slag, lime, puddle furnace cinder, and sand, according to the condition of the furnace. Iron pyrites from Strafford, Vt., was also used to prevent the possibility of salamanders of iron forming in the furnace. The amounts used were: —

Copper ore	656 lbs.
Old copper slag	292 "
Puddle slag	91 "
Lime	35 "
Sand	31 "
Pyrites	109 "
Coke	240 "

The yield of crude copper was 67 lbs., and of copper matt 77 lbs. 2 ozs., which, latter, when roasted and smelted with charcoal gave 41 lbs. 8 ozs. of copper, yielding a total of 108 lbs. 8 ozs., which in a partial analysis made by Mr. A. H. Pearson is shown to contain

	No. 1.	No. 2.
Lead	2.32	4.67
Copper	88.70	89.61
Silver	trace	trace

No. 1 is from the 41 lbs. 8 ozs. No. 2 is from the 67 lbs. of copper. The result shows that of the 131.2 lbs. which the ore contained, 108½ lbs. were saved, and 22.7 lbs. were unaccounted for in the yield. This loss results from three causes: — 1, the furnace did not clear itself at the end of the run, a considerable amount of ore was left

mixed with coke and slag; 2, the slag undoubtedly carries as much as $\frac{3}{4}$ of one per cent. of copper, but the amount has not yet been determined; 3, the loss in handling the matt and copper about the tap hole of the furnace. Of the 20 per cent. of copper 16.5 per cent. was saved.

REFUSE OBTAINED FROM THE CELLAR OF A TYPE FOUNDRY WHICH WAS BURNT OUT DURING THE BOSTON FIRE, NOV., 1872.

An experiment was tried by Mr. A. H. Pearson, with the view to answer two questions:—What amount of type metal the refuse contained, and what was the most feasible method of recovering the metal for the owners of the type foundry.

One hundred and eighty pounds of the refuse, when examined, seemed to contain sand, mortar, bricks, stones, shoe-pegs, charcoal, tacks, nuts, bolts, nails, etc., and type metal in the form it assumed, when, in the melted condition, it dropped into the sand.

At the outset it was evident that a water separation for the sand and metal would be needed.

The refuse was washed by means of a powerful hose, which carried away the lighter material and saved the heavier, and yielded three products:—

(*a.*) Coal, shoe-pegs, etc.
(*b.*) Sand.
(*c.*) Residue.

(*b.*) Sand weighed 100 lbs., and by assay yielded 1.73 per cent., which is probably small enough to reject in a mere temporary operation, like the recovery of metal lost in a fire.

(*a.*) Shoe-pegs, etc., contained no metal.

(*c.*) Residue which contained nearly all the metal was treated on a hydraulic jigger of one-sixteenth inch mesh sieve and yielded,

(*d.*) Skimmings.
(*e.*) Metal.
(*f.*) Siftings.

(*e.*) The metal was melted with charcoal in a large crucible, and yielded 34½ lbs. of good ingot type metal worth 11 cents per lb.

(*d.*) The skimmings weighed 20¼ lbs., and yielded 9.04 per cent.

of metal to assay, or in actual weight about 2 lbs. of metal which was not saved.

(*f.*) Siftings from the last jigger were treated on a thirty-second inch mesh jigger, and yielded three products: —

(*g.*) Skimmings.
(*h.*) Metal.
(*i.*) Siftings.

(*h.*) Metal when fused together gave 13 lbs. 2 ozs. of good ingot.

(*g.*) Skimming, weighed 8 lbs. 2 oz., and contained 19.3 per cent. or about 1 lb. 9 ozs. of metal.

(*i.*) Siftings weighed 8 lbs., and contained 53 per cent. of metal, or a little over 4 lbs.

Summing up the results, we find that the amount of ingot metal obtained was

(*e.*)	Metal	34 lbs. 8 ozs.
(*h.*)	"	13 " 2 "
		47 " 10 "

And that the amount of metal allowed to pass by was

(*b.*)	Sand	1 lb. 11 ozs.
(*d.*)	Skimmings	2 " 0 "
(*g.*)	Skimmings	1 " 9 "
(*i.*)	Siftings	4 " 0 "
		9 " 4 "

The metal in (*i.*) siftings was in good condition to save, and would have been treated on the large scale.

This experiment upon type metal has been introduced into this report to show how certain investigations may be made in these laboratories, as incidental and entirely subservient to the course of instruction.

Respectfully yours,

ROBERT H. RICHARDS,

Professor in charge of Mining and Metallurgical Laboratories.

THE INSTRUCTION IN ARCHITECTURE.

President Runkle:—

DEAR SIR: The instruction in the department of Architecture has, during the last year, followed the course laid down in the Catalogue, only differing from the work of the previous year in the organization of an advanced or Post-graduate course of study, in accordance with the recently adopted policy of the school. This has been effected, as was proposed in my last report, by separating from the undergraduate work the subjects of practical construction, specifications, and working drawings which the undergraduates have not time to pursue to advantage. Many of the special students have taken this advanced course in construction in the place of the scientific study of construction with which the regular students are occupied, simultaneously with the undergraduate course of design. The Post-graduate course of Design has not yet been organized.

Three Regular Students, and about twenty Special Students, have been in attendance through the year. Besides the studies strictly belonging to the course, Professor Warren has given the students in architecture special instruction in Descriptive Geometry, and I have myself given them a course of lectures on Perspective and the Perspective of Shadows. Mr. Létang has also given daily instruction in charcoal drawing during a

part of the year. The study of the history of architecture has been pursued more systematically than in previous years, the development of styles from the fifth century before Christ to the reign of Charles the Fifth being followed with a text-book, with lectures and such illustrations as our collections afford. The Trustees of the Boston Athenæum have kindly allowed us to use their excellent library of architectural works to supplement the deficiencies of our own.

The subjects upon which the class of design have been occupied, after the elementary work with which the year opened, are as follows: — 1. A monumental column; 2. An artist's house; 3. A railway station; 4. A monumental chapel; 5. A private museum of painting and sculpture; 6. A campanile; 7. The employment of four columns; 8. A pavilion between two bridges; 9. A village church; 10. A grand staircase under a vaulted ceiling or dome; 11. A Natural History building; 12. A school of chemistry; 13. A military and naval tomb. This last was drawn and designed in perspective.

Most of these works have been photographed on a small scale, as a memento and record of the year's work.

The collections have not been materially increased during the year, but a good deal of work has been done in arranging and cataloguing the books and photographs, and although not increased in numbers they are much more serviceable than they have hitherto been.

I am very truly
Your obedient servant,
WILLIAM R. WARE.

DEPARTMENT OF MECHANICAL ENGINEERING.

President Runkle: —

DEAR SIR: The professional instruction in this department is given in four courses: the mathematical, the practical, the graphical and the excursional. To complete the facilities we still greatly need an *experimental laboratory*, especially arranged with reference to this department.

In the first three courses the work is taken up in the same order, as in Professor Rankine's works on "Mills and Millwork," and "Steam Engine and other Prime Movers," which are used as text-books. All these courses are carried on together with the same class; each approaching the same subject from a somewhat different standpoint. In the mathematical course Professor Rankine's demonstrations are usually given; but care is taken to collect from his several books and papers all he has given upon a particular subject, that the simplest as well as fullest discussion may be presented to the class.

In the practical course the entire attention is given to the applications of the theory, as involved in practice. Applications, as far as possible, are made to existing engineering works, and to problems as they occur in practice.

In the graphical course the instruction is chiefly based upon good examples of American practice; and it is intended that

each exercise in theory, or practice, shall be supplemented by a drawing exercise covering the same ground. The subject of gearing happens, just now, to be the subject under discussion in the theoretical and applied courses; and the corresponding graphical work is making working drawings of a pair of bevel gears, designed by James B. Francis, Esq., of Lowell, and which now transmit the power produced by one of the largest turbines in the world. These gears have epicycloidal teeth; and as there are correct and approximate methods of drawing such teeth, students will draw them by different methods, and thus be able, by an actual comparison, to judge of their comparative correctness.

The excursional course is proving a very important one. Once a fortnight, or oftener, visits are made to establishments where machines are in use, or in process of construction. Each student is held responsible for some particular part of a machine or operation, which he must report upon, either in words, or by measurement and sketches. Afterwards a summary of all these reports is made for the benefit of the whole class, and as the basis of such further instruction upon the particular subject under consideration as may be desired. For the present I am indebted to Professor Lanza for valuable aid in the theoretical course, and to Mr. Schubert in the graphical course.

I am aware that a mechanical laboratory was a particular feature in the plan of instruction, as developed by President Rogers; and I beg respectfully to suggest that if we would see this department of the Institute take its proper position, the establishment of such a laboratory should no longer be delayed. After the conferences which I have had with yourself and Prof. Pickering upon this subject, I venture to submit the following outline of a mechanical laboratory, with such details as to use as a machine shop, and as an experimental laboratory, as time would permit.

In the first place this laboratory should be furnished with a certain number of the more important machine tools, and all

the adjuncts necessary to their use. Each student in the department should, early in his professional course, be required to become somewhat familiar with these tools by actual use, that they may afterwards be used to better advantage as models and types in the higher theoretical and practical instruction. If, at the same time, this laboratory should be used for the construction of models to illustrate the instruction in this as well as other departments of the Institute, it would furnish the student an excellent opportunity to see the great difference which often exists between drawings made to illustrate a design, and those which the experienced draughtsman will make for the actual construction of that design, for the purpose of securing the end sought with the least expenditure of materials and labor.

Another important part of the outfit for such a laboratory is the apparatus for making tests of power, efficiency, etc. Engineers are often called upon to make such tests in practice, and it is exceedingly desirable that students should have an opportunity during their professional course, to become acquainted with the means, and have practical experience in making such tests.

Such a laboratory should be supplied with its own steam boiler and engine especially designed and arranged for experiment; then, with thermometers, pyrometers, barometers, an indicator, a transmission dynamometer, an absorption dynamometer, a calorimeter, a chronograph, and apparatus for weighing and measuring, we could perform experiments to determine: — weight of fuel burned; weight of water evaporated; temperature of fire; temperature of escaping gases; waste of fuel in escaping gases; barometric pressure; pressure of steam in boiler; pressure of steam in cylinder; speed of engine; indicated power of engine; effective power of engine as measured by transmission and absorption dynamometers; value of Joule's equivalent; experiment on safety of boiler; comparative pressure and temperature of steam; latent heat of steam; evaporative power of various fuels; air required for combustion and dilution; distribution of fuel and air; rate of

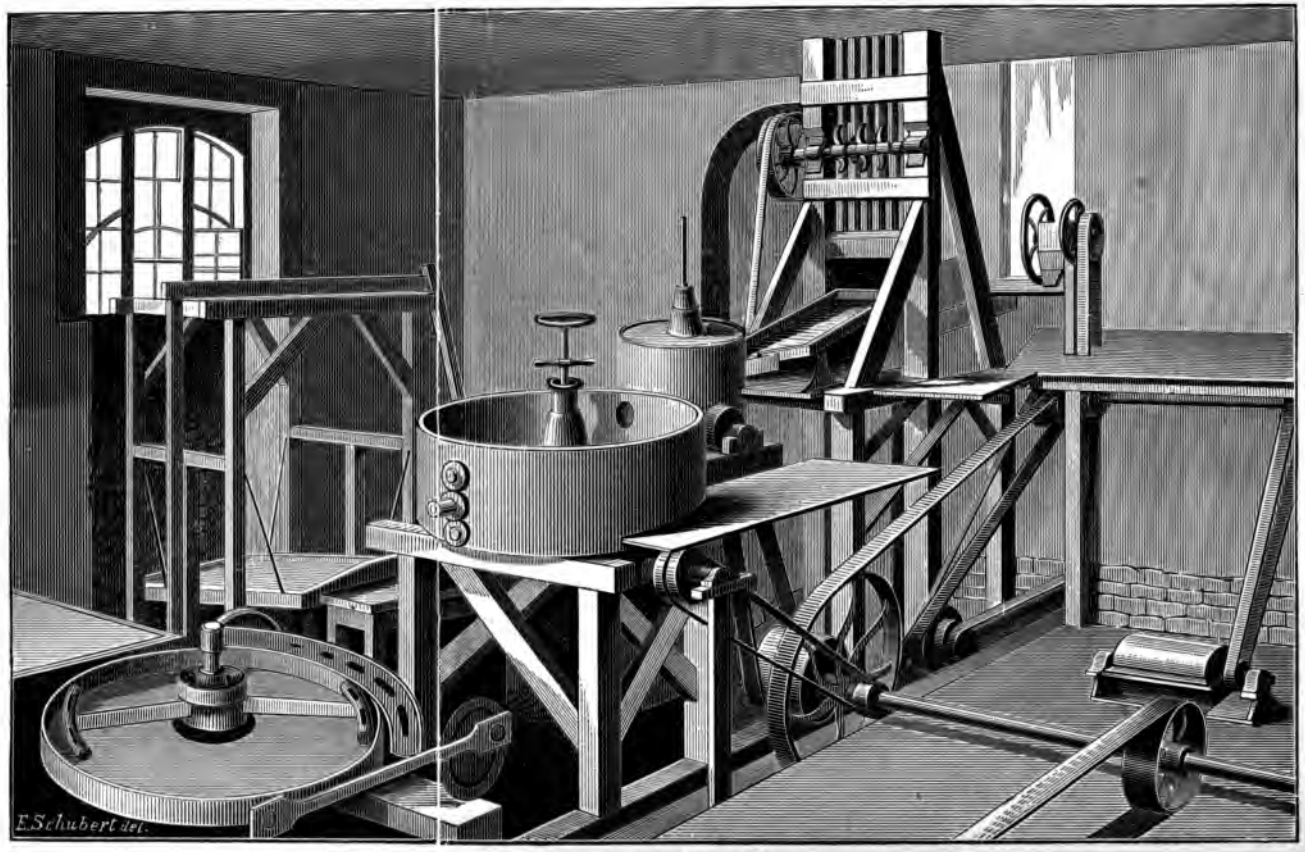
combustion; heating and cooling of gases and vapors by compression and expansion; proper and improper methods of setting valves; effects produced by superheating and wire-drawing steam; value of wrapping substances, as felts, cements, etc.; effects of steam jackets; efficiency of governors; uniformity or ununiformity of motion of fly-wheels, etc.

Such are some of the many experiments which could be readily performed in the laboratory for the instruction of students. But new questions are constantly arising, and this laboratory should always be prepared for their examination and solution.

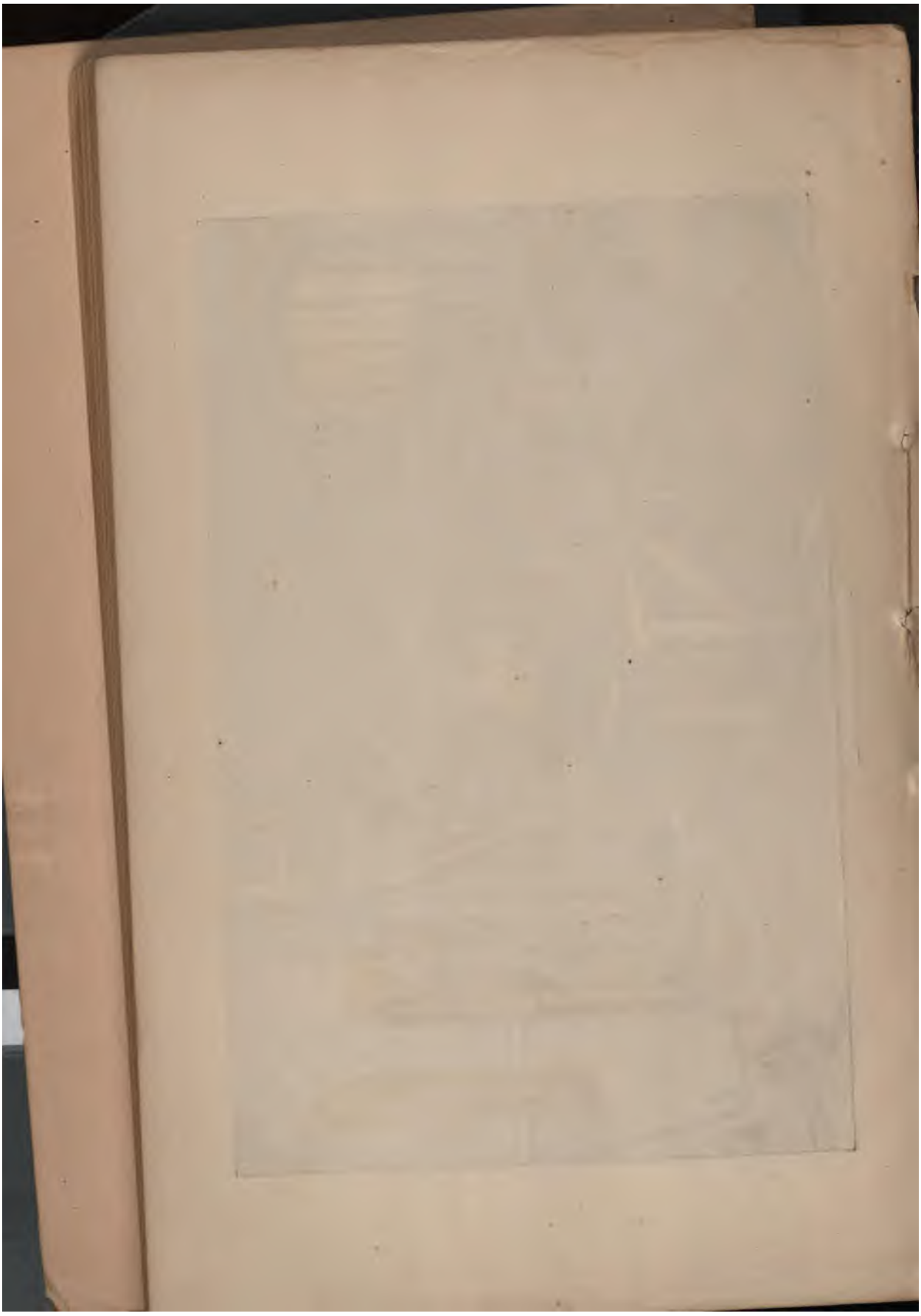
Very respectfully yours,

CHANNING WHITAKER.

Assistant Professor of Mechanical Engineering.



MINING LABORATORY.



Mr. William Amory.
41 Beacon St.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

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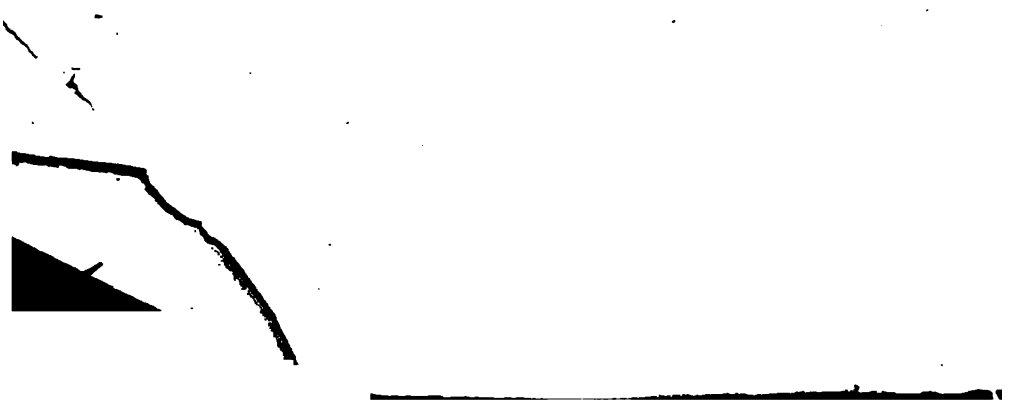
PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1876.

BOSTON:
PRESS OF A. A. KINGMAN.
1877.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY LIBRARY OF THE



MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1876.

BOSTON:
PRESS OF A. A. KINGMAN.
1877.

Extracts from Acts of the General Court of Massachusetts, in relation to the Massachusetts Institute of Technology.

Act of Incorporation. "William B. Rogers [and others named], their associates and successors, are hereby made a body corporate, by the name of the MASSACHUSETTS INSTITUTE OF TECHNOLOGY, for the purpose of instituting and maintaining a Society of Arts, a Museum of Arts, and a School of Industrial Science, and aiding generally, by suitable means, the advancement, development, and practical application of sciences in connection with arts, agriculture, manufactures, and commerce."

Chapter 183, *Acts and Resolves of* 1861.

Grant of Public Lands. "When the Massachusetts Institute of Technology shall have been duly organized, located, and established, ... there shall be appropriated and paid to its treasurer, each year, on the warrant of the Governor, for its endowment, support, and maintenance, one third part of the annual interest or income which may be received from the fund created under and by virtue of the 130th chapter of the Acts of the 37th Congress, at the second session thereof, approved July 2, 1862 [giving Public Lands to the States in aid of instruction in Agriculture, the Mechanic Arts, and Military Science and Tactics]. . . . . Said Institute of Technology, in addition to the objects set forth in its Act of Incorporation [as above quoted], shall provide for instruction in military tactics."

Chapter 186, *Acts and Resolves of* 1863.

Power to confer Degrees. "The Massachusetts Institute of Technology is hereby authorized and empowered to award and confer degrees appropriate to the several courses of study pursued in said Institution, on such conditions as are usually prescribed in universities and colleges in the United States, and according to such tests of proficiency as shall best promote the interests of sound education in this Commonwealth."

Chapter 247, *Acts and Resolves of* 1868.

CONTENTS.

President's Report . . . . . i–xxiv
Secretary's Report of Society of Arts 1–25
Spirit Compass 1
Extinguishing of Fires on Shipboard 3
The Liquid Compass. 4
Metric System of Weights and Measures 5
New Method of Topographical Surveying 7
New Wind Vane 8
Instrument for Drawing Curves 9
Differential Compass 9
New System of Rifling Cannon 10
Developments in Steam Engineering 12
Blood Globules of Man and Animals compared 14
Electric Railway Signals 15
Mining Laboratory of the Institute 16
Experiments on Sound 16
New form of Plane Table 17
Telegraphing Musical Sounds 18
School of Industrial Science, Attendance 22
Lowell Free Courses 22
Meetings of the Corporation 23
Department of Physics 26
Department of Philosophy 40
Department of Modern Languages 50
Lowell Free Courses 58
Light. Prof. Cross's Report 58
Kant's Critique of Pure Reason. Prof. Howison's Report 60
Physiology and the Laws of Health. Prof. Kneeland's Report 61
General Chemistry and Qualitative Analysis. Prof. Nichols's Report . . 62
Heat and its Applications. Prof. Ordway's Report. 62
Elementary German. Prof. Otis's Report 64
Elements of Perspective. Prof. Ware's Report 67
Abstracts of Theses by Graduates of 1875–76 69
Providence Water Works, by Thomas Aspinwall, Jr. 69
Merrimac River Bridge at Nashua, N. H., by F. W. Baldwin 70

West Chester Park Bridge in Boston, by J. B. F. Breed 70
The Buffalo Water Supply, by H. T. Buttolph 71
The Bridge over Front St., Worcester, Mass., by F. K. Copeland . . . 73
The Broadway Draw Bridge, Boston, Mass., by John R. Freeman . . . 74
The Albany St. Bridge in Boston, by F. W. Hodgdon 74
Iron Bridge over the Merrimac River at Tyngsboro, Mass., by A. L. Mills . 75
Design for a Double Track Wrought Iron Post Truss, by Henry Raeder. . 76
West Boston Draw, by C. L. Rich 77
Eastern Avenue Swing Bridge in Boston, by H. M. Waitt 79
Haverhill Highway Bridge, by H. B. Wood 80
A Mechanical Laboratory, by A. D. Blodgett 82
Steam Boilers, by C. L. Dennett 83
Modern American Locomotive Engineering, by F. E. Galloupe . . . 84
Paper Mills and Machinery, by S. Hollingsworth 89
Pumping Engines, by A. C. Kilham 90
Shafting and its Fittings, by C. T. Main 93
The Screw Propeller, by C. F. Prichard 95
The Port Henry Iron Industry, by C. F. Allen. 97
Treatment of an Argentiferous Galena from Burleigh Tunnel, Colorado, by S. James, Jr. 98
The Richmond Blast Furnace, by T. W. Robinson 99
Report on the Pomeroy Iron Works at West Stockbridge, Mass., by T. E. Schwarz 100
Newburyport Silver Lead Mines, by J. H. Susmann and W. D. Townsend . 102
Action of Tungstic Acid upon Gelatin, by W. P. Atwood 104
On Anthracene and Associated Hydrocarbons, by C. E. Fletcher . . . 104
Value of Tanning Materials, by W. E. Nickerson 105
Report on the Vershire Copper Mine and Ore, by R. H. Gould . . . 106
Catalogue of the Alcidae in the Museum of the Boston Society of Natural History, by W. B. Barrows 108
Geology of Eastern Massachusetts, by W. O. Crosby 109
On the Mean Specific Gravity of the Earth, by J. B. Henck, Jr. . . . 112
The Atomic Theory as Applied to Gases, by S. W. Holman 113
New Experiments in Sound, by W. W. Jacques 115
Australian Colonies of Great Britain, by C. A. Sawyer 118
Concerning Kant's Transcendental Æsthetic, by D. W. Phipps . . . 120
Historical and Logical Relations between Fichte and Kant, by R. C. Ware . 123
The Russian System of Shop-Work Instruction 124
Department of Military Science and Tactics 154
Lowell Department of Industrial Design 166
Department of Architecture 168
Mining Expedition to Pennsylvania 171
Appendix. Centennial Catalogue 175
Catalogue of Material collected at the Centennial Exhibition. 183
List of Members of the Society of Arts 232

PRESIDENT'S REPORT.

To the Corporation of the Institute: —

I deeply regret the delay in the issue of this report, which has been caused by the desire to include all matters relating to the International Centennial Exhibition held at Philadelphia during the year, and affecting the Institute. The particular cause of delay has been the time taken to prepare, in the midst of other absorbing duties, a full and accurate catalogue of the collections presented to us by exhibitors, which would have been practically useless without the systematic classification we have made, with the corresponding casing and catalogue. I shall touch upon some matters begun near the close of the year, which will be reported upon fully hereafter.

The various reports and matters herewith submitted will inform you of the condition of the several departments of the Institute for the year 1875–76. For information relating to departments not especially referred to, and in which no particular changes have taken place during the year, you will please consult the report of last year.

The changes in the corps of Instruction during the year have been the resignations of Lieut. E. L. Zalinski, Professor of Military Science and Tactics, Thomas E. Pope, A. M., Instructor in Quantitative Analysis, Frank B. Morse, S. B.,

Instructor in Free Hand Drawing, Francis T. Sargent, S. B., and J. Austin Knapp, S. B., Assistants in Mechanical Engineering, and William E. Nickerson, Assistant in General Chemistry and Qualitative Analysis. Lieut. Henry W. Hubbell, Jr., U. S. Art'y, was appointed Prof. of Military Science and Tactics, Thomas W. Robinson, S. B., Assistant in Quantitative Analysis, James B. Stanwood, S. B., and Clarence L. Dennett, S. B., Assistants in Mechanical Engineering.

Attendance. The aggregate number of students in attendance during the year was 299, an increase of 11 over the previous year. For classification and other items, see page 22 of the Secretary's report.

Graduates. The number of graduates for the year was 44, two of whom completed the course in 1872–73, with the exception of presenting a graduating thesis. This is the largest number ever graduated in one year. It will also be noticed that all but one of the ten departments are represented. The following table gives the aggregates in years and departments.

	1868	1869	1870	1871	1872	1873	1874	1875	1876	Total.
Civil Engineering . .	6	2	4	8	3	12	10	10	14	69
Mechanical Engineer'g	1	2	2	2	1	1	4	7	8	28
Mining Engineering .	6		2	5	4	2	1	6	7	33
Architecture						1	1	1		3
Chemistry		1	1	2	3	6		1	5	19
Metallurgy									1	1
Natural History . .									2	2
Physics								1	3	4
Science and Lit. . .	1		1			1	2	2	2	9
Philosophy									2	2
Total	14	5	10	17	11	23	18	28	44	170

Theses. Abstracts will be found on pp. 69–123. Mr. Galloupe's thesis has been published in full in the Journal of the Franklin Institute, and also a portion of Mr. Kilham's; those of Mr. Holman and Mr. Jacques in the Proceedings of the American Academy of Arts and Sciences; those of Mr. Barrows and Mr. Crosby have been accepted for publication in the

Proceedings of the Boston Society of Natural History; and those of Mr. Ware and Mr. Phipps, one published and the other accepted, by the Journal of Speculative Philosophy, St. Louis.

These facts are the only commentary I need make upon the general excellence of all the theses presented.

THE INTERNATIONAL CENTENNIAL EXHIBITION AT PHILADELPHIA, 1876.

The Institute's Exhibit at Philadelphia. Early in the year the question of the participation of the Institute in the Exhibition began to be agitated. There was a lack of unanimity in favor of so doing, and especially a lack of means to meet the necessary expense. These discouragements led to delay and decrease of interest, until late, and when the matter had about been given up, the State came to our aid in a small appropriation. We then hurriedly made such collections as were available, and represented as nearly as possible the current work of the school in the various departments. These collections were exhibited in the East Gallery of the Main Building, in one of the stair-ways leading to the Gallery, and in the Women's Pavilion, and were regarded by all as creditable to the school, and adding substantially to the credit and value of the State's exhibit of its educational resources and progress. The exhibit of the Lowell School of Design was thought worthy of a special award, as was also our exhibit as an whole. On application of Dr. David Murray, Commissioner of Education in Japan, the whole collection from the Lowell School of Design was presented to the Educational Museum of Japan. A recent letter from Dr. Murray speaks of these designs as a marked and interesting feature of the Museum. This Museum is mainly intended to illustrate the present condition of Industrial Art Education, and to serve in some degree to guide and stimulate such education in that country. The Catalogue of the Institute's exhibit will be found in the Appendix to this report.

The Institute's Centennial Excursion. From the beginning of our school, an important feature in the instruction of the higher classes has been the excursions to mining regions and manufacturing works relating to the various courses. This has been especially true of the mining department, which has for several years spent a portion of each long summer vacation in visits to the most important mining centres of the United States and Canadas. The students have been particularly prepared to profit by such excursions by their experience in the treatment of ores in our Mining and Metallurgical Laboratories. I may add here that these laboratories have grown from year to year in capacity and completeness of detail for doing almost all kinds of work, and on as large a scale as will ever be needed either for instruction or experiment; and they have, besides, demonstrated the feasibility of incorporating a large amount of practice in the curriculum of the school, and that, too, not only without curtailing the amount of purely scientific instruction, but by giving to this instruction point and definiteness. Contact with mines and mining operations, preceding such practical study, is of comparatively little value to the student or the mine; while the handling of ores by the ton in the laboratory particularly qualifies the student to rapidly profit by contact with the wider sphere and conditions of mining works. Besides, he begins by being an aid rather than an hindrance to the works, because he is not entirely ignorant of the elements of practice.

The success of these laboratories is beginning to show us more clearly the possibilities and advantages of such facilities in other engineering departments. There is a certain knowledge which can only come to the mind by the ability to handle the materials with which we deal, and if this training of the hand can be formulated into an educational system, and pursued by educational methods, we shall have engrafted upon our industrial education a very important and vitalizing element. The experience of the works must, as far as possible, be brought into the school in order that the training of the school

may properly and most profitably react upon the works. All the sciences and arts which find their applications in industrial works should be thoroughly taught in the schools, and there is no more difficulty in teaching the arts in a practical way, when they have once been comprehended as such, as they will be when studied as a whole, and not through some special application, than there is in teaching the sciences as such, or in their applications. But the *manual* of an art can only be formulated and taught by an expert in this art, and it is only through such a course of instruction as a basis, that we come to see the vital connection between science and art in their relations and applications in the various industries. Our system of excursions naturally led us to consider the feasibility of a trip to Philadelphia during the Centennial Exhibition. But too many were anxious to go; none of the departments which had been in the habit of arranging and conducting excursions of small parties were willing to undertake one on so large a scale. At last the Military department came to our aid. The organization which had been found necessary for properly carrying on the instruction of the department, was found sufficient to maintain order and cohesion in a much larger body, and the Institute, as well as all the members of the party, owe a debt of gratitude to Lieut. Zalinski for the energy and efficiency with which the whole affair was conducted; and it gives me great pleasure to refer you to his interesting report, where you will find full details of all matters connected with the expedition, except the presentation to Lieut. Zalinski of a valuable watch and chain by the members of the party, in recognition of his aid in planning and conducting the expedition. This presentation was also made the occasion by members of the Corporation present, as well as by professors and students, to cordially thank him for what he had done for the school in the reorganization of the Military department, in the building of a proper drill hall and gymnasium, and in the establishment of a restaurant where well cooked and well served meals could be had at a reasonable price.

I gladly take this opportunity to thank Lieut. Zalinski in behalf of the Corporation, and to wish him success in all his future duties and relations.

It was supposed that much special study would be done and reported upon by the students of the several departments. In this expectation we were to a considerable extent disappointed. While the heads of departments were able to aid their students in finding what related particularly to their work, and to guide them in a general way, the excitements and fatigue of each day left little power or desire to take full notes, and still less to write them out for the instruction or inspection of others at the end of the day. Notwithstanding this apparent, not real, failure to accomplish the result in a given way, the exhibition proved a grand lesson to all of us, and I am happy in believing that the Institute is only just beginning to reap the fruits which in succeeding years will reach greater maturity and value.

The Centennial Collections. When our party disbanded, I felt convinced that the Institute could reap an additional advantage if some one could be on the ground to gather up such materials as would in all probability be given to institutions, or sold at low rates, rather than packed and returned home at greater or less cost. Mr. A. D. Blodgett, one of the graduates of 1876, was selected for this duty. He began work July 1st, and remained in Philadelphia until the middle of December, after he had packed and shipped his collections to Boston. Since his return he has taken charge of the arranging and cataloguing the collections, the results of which you will find in the Appendix. These collections could have been made much larger and more valuable if we had had but a small sum to expend in this way. Not an article was purchased, our only expense being the packing and sending to Boston.

At the same time, Mr. Blodgett took charge of the Institute's exhibit, and distributed about 8000 copies of various catalogues and reports to individuals, and to foreign countries, through their Commissioners. It was by this means that many of the

collections were obtained, and relations were established which can not fail of continuing to be of advantage to the Institute.

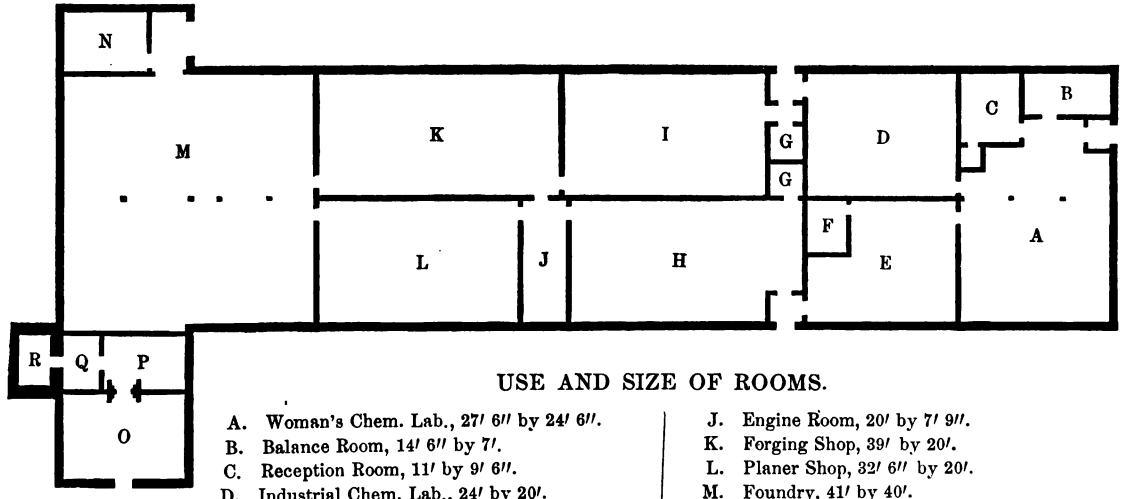
We have thus formed the nucleus of the Industrial Museum, which was a prominent feature of the Institute in its Act of Incorporation. With proper space and care this Museum would grow rapidly at a very inconsiderable annual cost. This matter deserves your serious attention.

THE NEW TEMPORARY BUILDING FOR SHOP-WORK AND ADVANCED CHEMISTRY.

The New Building. The plan of the building authorized by your vote of Aug. 17, 1876, is given on the next page. It is of one story, with 12′ brick walls, nearly flat tar and gravel roof, well lighted, heated, and ventilated, and covers 7500 sq. feet. The stem of the T, 150′×40,′ was first built, but finding greater demands upon the space than was expected, we afterwards made an addition of 75′×20′ parallel to Newbury St. Some changes in the details in the heating of the main building has given the heat and power needed in this building without any addition of boiler capacity. The funds for the erection, heating, and equipment of this building have been contributed by the Women's Educational Association, the Massachusetts Charitable Mechanic Association, and various individuals, details of which will be reported hereafter.

A. *Women's Advanced Chemical Laboratory.* With the exception of the years 1869–70 and 1872–73, chemistry has been among the Lowell Courses since their establishment in 1865–66. The instruction in this subject has been given mostly through laboratory work; and as the courses have been open to both sexes, quite a large number of women, residing in and about Boston, have been able to acquire a good knowledge of General Chemistry aud Qualitative Analysis. This fact led the Women's Educational Association of Boston to apply to this Institute to furnish advanced chemical instruction to women. By your vote of May 10, 1876, such instruction was author-

NEW TEMPORARY BUILDING FOR SHOP-WORK AND CHEMISTRY.



USE AND SIZE OF ROOMS.

A. Woman's Chem. Lab., 27′ 6″ by 24′ 6″.
B. Balance Room, 14′ 6″ by 7′.
C. Reception Room, 11′ by 9′ 6″.
D. Industrial Chem. Lab., 24′ by 20′.
E. Microscopical Lab., 24′ by 20′.
F. Dark Room, Spectroscope.
G.G. Tool and Stock Rooms, 6′ by 6′.
H. Lathe Shop, 37′ by 20′.
I. Chipping and Filing Shop, 32′ 6″ by 20′.
J. Engine Room, 20′ by 7′ 9″.
K. Forging Shop, 39′ by 20′.
L. Planer Shop, 32′ 6″ by 20′.
M. Foundry, 41′ by 40′.
N. Wash Room, 13′ 6″ by 9′ 6″.
O. Organic Chem. Lab., 19′ by 14′.
P. Special Work Room, 13′ by 9′ 6″.
Q. Store Room, 9′ 6″ by 6′.
R. Ice Chamber, 8′ by 5′.

ized, provided the Association would aid in securing the funds to provide the proper laboratory and equipments. The Association promptly performed its part by raising for this purpose about $2000. The laboratory, balance and reception rooms, are devoted exclusively to women, and will accommodate about twenty students. The space devoted to this laboratory was placed in charge of Professor John M. Ordway, to whom we owe the excellent and commodious arrangements, and under whose personal supervision and instruction the department has realized the highest expectations of all concerned.

E. *The Microscopic and Spectroscopic Laboratory.* The theory and use of these instruments constitute a part of the general course in physics; but the need has long been felt for the proper facilities for applying them in other subjects of study. By an ingenious seating devised by Professor Ordway, the table supporting the instrument is so connected with the dissecting table that the student turns from one to the other without leaving his seat. Each table is supplied with gas and water. The laboratory accommodates ten students at a time, and is a model of convenience and compactness of arrangement. It is in charge of Prof. Ordway, is open to all students in the school requiring this instruction, aud is a valuable and interesting adjunct to our resources.

D. *The Industrial Chemical Laboratory.* For some years the chemical department has felt the urgent need of more room. This has been especially needed in Industrial and Organic Chemistry. The opportunity for providing temporarily for these wants has been offered in the new building. The kettles for dyeing are already set, and the various furnaces and other appliances will soon be in place.

O, P, Q, R. *The Organic Chemical Laboratory* is separated from the remainder of the building by a brick wall and is substantially fire-proof. The benches and hoods are of stone, and the floor of cement. It has been admirably arranged in all its

details by Professor Wing, and was built and fitted at his own personal expense, assisted to some extent by a few friends. It will be noticed that the additions to the resources of the chemical department of the Institute, to which I have called your attention, are of a marked and substantial character, and I am happy to say that for breadth, thoroughness, and efficiency in all the details of the instruction we have every reason to be fully satisfied with the present condition of the department.

THE RUSSIAN SYSTEM OF INDUSTRIAL ART EDUCATION.

In the report which I had the honor to make upon this subject soon after my return from Philadelphia in July last, it was seen that the Russian Government had decided some years ago, that in the education of mechanical engineers and machinists, practice should be combined with theory, to the extent that the young engineer should be able to construct his own designs with his own hands. To this end large manufacturing works were connected with the Imperial Technical School of Moscow, which has solicited and executed orders to the amount of thirty-five to forty-six thousand dollars annually. These work were thoroughly organized, with competent engineers at the head of the various departments, with a sufficient number of skilled workmen, and conducted as a commercial establishment. To these large and well appointed works the students were admitted for the purpose of acquiring manual skill and professional practice without any preparation, until 1868. During these years the system of apprenticeship was tested as a part of an educational system under the most favorable conditions. It failed. Unskilled and intermittent labor was found prejudicial to commercial success, while it was also found impossible to develop the manual skill of the students in a systematic and progressive way, with the proper tests for thoroughness and efficiency at every step, with the greatest economy in teaching and supervision to the institution and of time to the student. Since 1868 that system of art teaching has been pursued which

produced the surprising results exhibited at Philadelphia. Here then we have in the experience of this great school, gained through a number of years, a comparison of the two systems; the one of teaching the arts indirectly through their applications in the manufacturing works, and the other of teaching the arts directly as such, and as preliminary and preparatory to admission to these works.

It is indeed true that after the arts have been learned, the next logical step in a full course is to teach their applications through constructions, either in private works, or as is done in the Moscow school. In a government school, when the curriculum covers six years, and the young engineer is needed in the service immediately upon graduation, and has not the opportunity, for any reason, to learn the details of construction in private works, then the attaching of the works to the school may be justified.

I propose now briefly to call your attention to the shops which we have thus far been able to establish, reserving for my next report a full exposition of the system as we have applied it, giving cuts showing the blanks as they come to the student, and also the finished work, with tables of results, showing the percentage of accuracy obtained by each student on every piece of work in each course.

I. *The Vise Shop for teaching the Arts of Chipping, Filing, etc.* In the fitting of this shop I wish to express my great indebtedness to Professor Whitaker, whose practical experience enabled him to judge of the value of the system, and to work out the details of the instruction and supervision which have been so ably and satisfactorily carried out by Mr. Wallburg, who has had the immediate charge of this shop.

The shop contains four heavy benches, each 18 ft. long, 3 ft. wide and $2\frac{1}{2}$ ft. high. To each bench eight vises are attached. It was supposed that one teacher could instruct thirty-two students at a time, and this has been found to be about the right number. At the beginning of the course it is quite enough,

but later, when the students have acquired some skill and independence, a larger number might be successfully taught. As an experiment, we have adopted for this course thirty lessons of four hours each, giving three lessons per week, which is certainly enough for the mechanical engineers, and probably also for the class in the new "School of Mechanic Arts," at first called the new course in Practical Mechanism. At each vise there are four drawers, each large enough to hold all the tools needed by the student at any one time; so that four sections of thirty-two each can take the course simultaneously. This shop has, then, a capacity for teaching the course to 128 students every ten weeks, and to 640 in a year of fifty weeks.

The next step was to devise the proper series of designs to teach the use of the various forms of files and chipping chisels used in any branch of the art, and with a range wide enough to cover all probable applications. At this stage the services of an expert were needed, and we were most fortunate in finding in Mr. Valentine Wallburg, a man who had spent twenty-five years in applying his art skill in various trades, and who had, moreover, the ability to comprehend the unity involved in the details, which he had spent so many years in applying. Each piece is designed to teach a definite idea, and to be put into the course when the student has acquired the requisite skill to work it. As the class system is to be followed, the element of time must be the same for all. The teacher is required to solve each piece in advance of the class, to find the time it will take, having also to settle clearly in his own mind the best method of solution, with the reasons why. At the beginning of a lesson the teacher must be able to assign the time to be given to the class to solve this piece, to show them what it is intended to teach, and to give them the method of solution, with the reasons therefor. These points settled, and all needed directions having been given, all proceed to do the same work, and the teacher's time and energies are all devoted in directing and watching its progress. When the assigned time has expired, all the pieces are called in for inspection, in accordance with an

analysis which has previously been posted, assigning marks to each element for perfect workmanship. These marks add up 100, the same given for perfection in other studies.

The student, by carefully studying the analysis, is able to work, not at a venture, but with knowledge, for the highest marks, and thus his capacity to judge of the quality of work fully keeps pace with his ability to perform it.

We are thus developing the mechanical judgment of the student by making in advance a careful study of the methods of solution, as well as the manual skill to perform, and the ability to judge of the quality of work at the same time. The course in mechanical drawing, which keeps pace with the shop work, and the parallel lecture-room course upon the same art, with its applications in construction, completes the instruction.

That so much skill of hand could be acquired in one hundred and twenty hours' practice has been quite as great a surprise to mechanics as to others, and I am glad to be able to say now from our own experience, and in which I am joined by all with hardly an exception, that the system is a triumphant success.

K. *The Forging Shop.* This shop is fitted with eight forges. The Sturtevant pressure blower, which furnishes the blast for the forges, is placed in the engine room. The hoods over the forges are connected with a 16′ pipe, which runs longitudinally near the ceiling of the shop, and enters a No. 4 Sturtevant exhaust blower just through the partition into room M, and thence through the embankment and foundation of the main building into a flue at its northerly end on Newbury St. This exhaust blower removes completely all smoke and dust, and much of the heat, making this shop one of the best ventilated and most comfortable rooms for work in the Institute.

As the acquiring of manual skill in the art is the principal aim, only such tools are furnished as are necessary to this end, but none of the appliances which are simply used to facilitate work. In establishing this shop it was supposed that two students could work at the same time at each forge, thus giving

sixteen to a section. But in this we have been disappointed. It has been found that considerable skill in the management of the fire, and the use of all the tools, including the sledge, must be gained before two can advantageously be put at the same forge upon two-handed work. On this account the students have had thus far only half the time in the shop that was intended. But even this short time of sixty hours has fully demonstrated the value of the system in teaching this important art, both in the quality and amount of work. You may be interested in a brief statement of the analysis of the art upon which we have based our course of instruction. In the infancy of the art the forger was obliged to operate upon irregular shaped masses of metal and work them into the required form and dimensions. Now the manufacturing works furnish us with iron and steel bars of any given shape and size in cross-section, and with this material the forger has to deal.

Now it is found that the forger's art is substantially included in the six following elements: First, *the management of the fire*, and *degrees of heat*; second, *bending without changing the cross section*; third, *drawing-down*, or reducing the cross section; fourth, *jumping*, or *upsetting*, that is, shortening the piece and increasing its cross section; fifth, *building up*, or *welding*; sixth, *hardening* and *tempering*. Now while the class are studying the forger's art in the class room, under the direction of the professor, either through lectures or some text upon the subject, such as is found in the "Practical Metal Worker's Assistant," by Oliver Byrne, they are at the same time in the shop working out under the direction of an expert a sufficient number of graded examples under each of the above heads to become familiar with the theory, and acquire reasonable skill in the manipulations. I am satisfied that it is of comparatively little use to spend much time upon these subjects without the instruction can be based upon a reasonable amount of practice — but with such a sub-stratum upon which to build, the whole subject becomes permeated with light and life. For instance, it is of little importance for the student to know the fact that

in tempering, certain tints accompany certain approximate temperatures, if he can not have the opportunity of studying these relations by actual practice, and learning at the same time how these facts are related to the uses of the tools he may be called upon to forge and temper.

While it may be true in general that for tempering steel tools for metal working, from 430 to 450 degrees of heat are needed, and that very pale straw yellow indicates about 430 degrees, and a shade of darker yellow about 450 degrees, it becomes especially and doubly true to the student who has once made and successfully tempered such a tool.

I must not close my brief account of this shop without expressing our obligations to Mr. B. F. Sturtevant of this city, who aided in working out the plan of this shop and fitted it at his own expense. He not only came to our aid with his large and successful experience as a skillful manufacturer of just what we needed to make the shop a perfect model of comfort and convenience, when such aid was of the greatest value, but he also expressed his confidence in the method of instruction we had adopted by this generous contribution, with a heartiness and cordiality which entitles him to my lasting gratitude and regard.

We were also fortunate in finding for the teacher of forging, Mr. James Bell, who has devoted forty years of his life to the practice of this art, and who by his skill, zeal and enthusiasm, and thorough comprehension of the system, and faith in its success made it such with every one of the fifty-one pupils who came under his instruction. That we should have found masters of two important arts, Mr. Wallburg and Mr. Bell, both so skillful, and at the same time having an apparently intuitive tact for teaching, is to me a matter of no less surprise than pleasure, and I gladly put on record my personal thanks to both of these gentlemen for the hearty and unfaltering support they have given me in all the details of instruction and discipline.

H. *The Lathe Shop.* In addition to the Vise and Forging Shops already mentioned, it is proposed as fast as the means can be secured, to furnish facilities for teaching the use of machine tools and foundry work, and thus complete the circle of the arts which apply particularly in constructions of iron and steel.

The lathe will be regarded as the fundamental machine tool, and after the student has become familiar with its construction and adjustments, and the tests for precision, he will be required to work out a series of designs, involving as a whole the entire capacity of the tool. All the other machine tools are to be regarded and used as supplementary to the lathe, and the lathe course is to be so designed as to include their use to the extent that experience may render necessary.

L. *The Planer Shop* is to be used for the supplementary tools, and it is thought that the shops H and L will furnish all the space needed for as many tools as one teacher can superintend successfully. American machine tools are now made of such variety and perfection that their skillful use is to be classed high in the scale of metal working arts, and it is only by personal familiarity with these tools that the engineer can ever acquire a tangible and exact knowledge of their capacity and their proper use by those under his direction. It is admitted that to-day there are far too few men in the shops who can use some of the more complicated tools with anything like the requisite skill, and still fewer who are able to adjust and test their accuracy within given limits. It is useless to ask for a degree ef accuracy which the tool can not give through faulty construction, or through incompetent handling. The work in these shops is to be made auxiliary to the class room instruction upon the theory and construction of these tools.

M. *The Foundery.* The founder's and the forger's arts are fundamental in all metal constructions. To these we look for the first close approximation to the forms we wish to construct,

and in a complete system of art instruction in metal working, one is quite as important as the other. Nor is there any reason either on the score of space or expense, why the founder's art should be omitted. All the important manipulations in the art can be as well learned in the moulding and casting of a good variety of small forms, as of large ones; the difference consisting mainly in the handling, which usually depends upon special devices, and is not in any sense a part of the art.

When the proposed series of shops are fully equipped, it is easy to see how the instruction in the foundery and the forging shop can be connected with the courses of instruction in the vise and machine tool shops; and especially will the series be complete when we shall have the room and means to establish a pattern shop. Then the student will be able to take his own drawings into the shops and follow them up till the design is brought out in its finished state, either in cast or wrought iron. And further, all this can be done by rigorously following the class system of instruction, applying at each step the most rigorous tests for thoroughness of workmanship. But a comparatively small sum of money is still needed to carry out this plan fully, and I can not but feel that when the importance of this system of art-education is once clearly seen, not only in connection with technical schools, but as supplementing our present public school system, the means will not be wanting to enable us to work out the plan with care in all its details.

You will be pleased to learn that by a recent letter from the Director of the Imperial Technical School of Moscow, I am informed that the Russian Government has authorized him to duplicate the exhibit of that school at Philadelphia for the Institute of Technology.

The Lowell School of Industrial Design. The continued demand for the graduates of this school is the best evidence I can offer of its success. Each year is adding to its efficiency as a school of design; but there is beginning to be a demand made upon it which it has not yet been able to meet. These

young designers can not put their designs upon the loom and exhibit them in the woven fabric, and this art is so closely allied to that of designing that it should be taught in close connection with it.

In foreign schools for teaching the arts employed in the textile manufactures, two phases of the weaver's art are usually kept in view — one that mentioned above, and the other the handling of the loom after the work has been properly mounted. This latter point, I am satisfied from the slight experience we already have, is not important for us to consider. We find that the students have no difficulty in running the loom after a few hours' instruction and experience. In a large manufacturing town I can see that it may be more economical to teach simple weaving in a school, than to be troubled with raw hands in the mills, but for us the question is simply the teaching the student how to make his weaving pattern from the design, and then put it properly upon the loom, and weave enough to show the design in the fabric; and for this purpose hand pattern looms are on many accounts better than power looms. The expense of running power looms is too great simply for pattern weaving, and besides the weaving of a pattern should be done slowly to give the student time to observe the working, and become familiar with the effects of each phase of the design as it appears in the fabric. It is important, however, that the school should be supplied with specimens of several of the more successful power looms of various construction, that they may be used and studied as machines, and some knowledge gained of the adaptability of each for the production of a certain class of goods. The theory and practice of dyeing and sizing come in the Department of Industrial Chemistry. Our wishes in this matter coming to the attention of the Lewiston Machine Co. of Lewiston, Me., we were kindly presented with one of their looms, which has been used for weaving quite a number of designs, and has given great satisfaction to teacher and pupils. We are also indebted to Mr. Edward A. Brigham of Boston, for an English loom, intended for the weaving of plain cotton

cloth and to be run as high as 225 picks per minute; and also to the Bridesburg Manufacturing Co. of Philadelphia, for one of their manufacture; neither of which we have yet had time to set up and use. Other parties have promised to aid us in this way, and we shall have no difficulty in adding this art to our course in designing. Messrs. Mudge, Sawyer & Co. have kindly furnished us with all the yarns needed, from the Washington Mills at Lawrence.

Industrial Science and Art. In what precedes it will be noticed that some prominence is given to the matter of Industrial Art. It has been the spirit of our instruction in all departments to combine theory and practice, that is, science and art, just as far as was practicable in a school. Even in the study of science, the practice, or art side, has been made prominent through our laboratories; and our teaching has been successful almost in the exact proportion to the extent in which we have been able to build the instruction upon a manipulatory, or art basis.

This sort of science teaching is of comparatively modern invention; and this inversion of building the theory upon the practice, or the science upon the art, is only gradually working its way in the teaching of the purely industrial arts through practice shops as a foundation upon which to build, in the mind of the student, a knowledge of the theory or science, which pertains to each, and which is mainly the experience of its practitioners, growing out of all the varying conditions of the applications. As, however, there is a time when science grows out of its corresponding art, so also there is a time when the art grows out of its applications in the trades, or handicrafts; and it becomes a matter of the greatest importance as to which phase of this development we use as the foundation of our industrial education.

In the past, the higher industrial education has been based upon the science phase, and the lower upon the trades, or handicraft, phase. It seems to me that in the future we shall

find it the wisest to build upon the art phase, as the firm and substantial foundation for both the engineer and the artisan, for both the theorist and the practitioner, no matter what the industry may be. Because if the student only acquires the art, he can apply it in the trades as a means of support, while upon the art as a foundation he may build a structure worthy of his highest aspirations.

Conclusion. I am glad to be able to say that the year's work has, upon the whole, been successful. There has been progress in all departments. We have only to regret the want of means to make the work still more successful. Not a single department has the means of meeting its necessary current expenses. In some a small appropriation is made to answer; in too many the minimum needs are made up by the professors; and the necessity for such contributions will last until a larger percentage of our income is derived from invested funds. There is no school or college in the country, so far as I know, whose students' fees constitute anything like such a large percentage of the total income; and I am sorry to know that our fees make it impossible for many young men to join our classes who would otherwise gladly do so. Nor have we the means for aiding needy students possessed by nearly all the older colleges. I refer to these facts here, hoping they may thus come to the attention of those who may be inclined to lend a helping hand.

JOHN D. RUNKLE, *President.*

SECRETARY'S REPORT FOR 1875–1876.

SOCIETY OF ARTS.

There have been held during the year fourteen meetings of the Society of Arts. The first two meetings were devoted to the discussion of the manner in which, if in any, the Society would coöperate with the School of the Institute in the Centennial Exhibition of 1876 at Philadelphia. Though the members consulted were all in favor of such representation, and a committee was appointed to consider the subject, the Society, as such, did not coöperate with the School in its exhibition, which proved of such great advantage to the students and an honor to the Institute — an account of which will be found elsewhere.

SPIRIT COMPASS, ETC.

At the meeting of *Dec. 9, 1875*, Mr. David Baker exhibited and explained the most important features of the so-called "Baker Compass."

The object of his invention was to remedy the defects of spirit compasses, the most prominent of which are: — 1. The liquid with which they are filled is liable to freeze in low temperatures, rendering the instrument useless for the time being. 2. The changing of the paint on the card and interior surface of the bowl from white to dark brown, making it difficult to distinguish the division marks. 3. The inconvenience and expense of taking the card to pieces in order to get at the needles to recharge them when necessary. 4. The leaking or

bursting of a card float at. sea, rendering the compass inoperative. 5. The inability of a floating card to turn in the liquid with a desirable degree of activity, in consequence of the friction produced by the float and needle casings. 6. The arrangement and movement of the lubber point.

These defects Mr. Baker claims to have overcome by the following corresponding remedies: — 1. His compass is filled with a thin, transparent kerosene oil which cannot congeal under any temperature to which it is liable to be exposed. 2. His paint is very firm and durable, perfectly imperishable in the oil, and will not scale, crumble, nor wash off; neither will it change to a dark color by the lapse of time. 3. The oil prevents oxidation of the needles and pivot, permitting the construction of a very light card, consisting simply of a sheet of paper with open centre, supported by a thin and narrow rim of metal or other suitable substance, to which the needles are fixed. This permits the direct application of a magnet to the needles, without removing them from the card whenever it is necessary to re-charge them. 4. No float being used or required, the compass can not become inoperative by a card-float leaking or sinking down on one side. 5. The light and thin card, displacing but a small quantity of liquid, and having no weight of casings around the needles and no float to create friction, turns very easily on a steel pivot, maintaining or regaining quickly its position in the magnetic meridian. 6. The lubber point, as usually made, is very deceptive, misrepresenting the direction of the vessel, and has doubtless been the cause of many disasters at sea; it leads the mariner to suppose that he is sailing on a straight line when he is really making a zigzag course; it may appear from this that he is sailing on a particular course, when he is actually sailing some degrees off.

By a simple apparatus attached to his and the old form of compass, he showed that at sea the inaccuracy in the latter was great in proportion to the roughness; when the vessel mounts a wave the bow turns one way off from the course, carrying the lubber line with it; when it descends into the trough of the

sea, it goes rapidly to the other side; so that this line, though indicating the long axis of the vessel, by its swinging motion constantly deceives as to the true course of the vessel; in fact, the experienced helmsman steers more by the direction of the waves and the sails than by the lubber line.

The whole secret is in this: In the old instruments, in every nation, the outer gimbal ring on which the compass swings is suspended on pivots on each *side*, so that any change in the elevation of the bow and stern of a vessel, except in an absolutely vertical plane, must be attended by an oblique motion, which carries the lubber line to one side or the other of the supposed course. He swings his compass on gimbals whose pivots are arranged in the longitudinal instead of the transverse axis of the ship, or *fore and aft*; this deviation of the lubber line thus becomes impossible, and the compass, instead of being an uncertain guide, becomes entirely trustworthy.

EXTINGUISHING OF FIRES ON SHIPBOARD.

Lieut. F. M. Barber, U. S. N., read a paper, illustrated by drawings on the black-board, on extinguishing fires on vessels laden with coal, cotton, or other combustible material. He utilizes the well-known properties of carbonic acid gas in the following way.

In some convenient locality on board, as the spardeck, he places one or more flasks, about three feet long and one foot in diameter, containing about one hundred pounds of the gas in a liquid condition; from the top of the flask runs a small iron pipe, just under the deck, the whole length of the ship; from this, at proper intervals, are branch pipes at right angles, passing to every store room and the hold; any one, or all the cocks, may be turned from the main deck, near the flasks.

On an alarm of fire the hatches are to be battened down, and the gas let on to the compartment where the fire is; the liquid gas, under a heavy pressure, passes in the form of vapor through the pipe, and is instantly driven to the compartment to

which it is admitted; arrived at this point, being one and a half times as heavy as air, it fills the compartment from the bottom upward, without being diluted by the air, producing at the same time intense cold by its expansion, and driving before it through cracks and crevices every particle of air.

The liquid is non-corrosive, and the vapor is not injurious to the most delicate fabrics. It is probably the only substance which will permanently suppress the most advanced stage of combustion in a cargo of coal. One pound of the liquid is equal to over eight cubic feet of gas; it must be contained in vessels capable of sustaining the great pressure.

The objections to its use, viz.: the want of apparatus capable of producing a large quantity in a short time and at a low cost, and of suitable vessels to contain it, have now been removed. He described the apparatus, devised by Mr. W. N. Hill, which produces fifty pounds of liquid gas per hour, at a cost of only fifteen cents a pound. The containing flasks are made of steel, weighing a little over three hundred pounds, and tested to two thousand pounds per square inch, hydraulic pressure; tested to destruction, one gave way at three thousand one hundred and thirty-two pounds per square inch. The flasks are made of sheets of steel, rolled up like curl-papers, one within the other; the outer one is riveted, and all spaces between the sheets are filled with pure tin.

THE LIQUID COMPASS.

December 23. Mr. Edward S. Ritchie read a paper on the "Baker" or "liquid compass," replying to the statements made at the last meeting.

In his compasses he uses alcohol and water, the first of which has never been frozen; the mixture he uses he has never known to freeze when in use on board ship. On examining the "Baker" compass he found the liquid used was naphtha, a highly volatile and combustible liquid, vaporizing and burning at all temperatures. Though this will not affect the paint of

the compass, nor congeal at any temperature to which it is likely to be exposed, it is, he thinks, very objectionable; it is very volatile and difficult to hold, very expansive when heated, requiring a compensation of much greater capacity than alcohol and water, and increasing the danger of bursting the bowl by heat or cold.

Placed as a compass generally is, in a close binnacle, with a lamp lighted inside, if from any cause a leak should occur, a dangerous explosion might result. The changing of the color of the paint is now practically corrected. The magnets are never charged until the cards are ready to be placed in the bowl, and it would be quite practicable to charge them in the bowl. The leaking of a card is possible, but extremely rare, as each one is severely tested under high pressure; his card bears but about forty-five grains on the pivot, while in the new compass it bears with a pressure of half an ounce.

Mr. Ritchie also stated that placing the lubber line in the line of bearing of the gimbal ring was not new, as the ships of the American and English navies had for many years been furnished with compasses whose lines were placed in this position; he had himself made hundreds in this way, and it is by no means certain that this is the best position.

METRIC SYSTEM OF WEIGHTS AND MEASURES.

Mr. Edmund H. Hewins read a paper on the "Metric System," which has been adopted by a majority of nations, including the United States. Standard metres are now deposited at Washington. England is almost the only important government which still withholds its approval.

It is so simple that any person of ordinary intelligence can readily be taught it in a few hours; and no one could pretend to master the old system of apothecary's, avoirdupois, and troy weights, and the inches, feet, yards, fathoms, furlongs, miles, perches, acres, pecks, bushels, gallons, quarts, pints, gills, etc., in many weeks — to say nothing of the general uselessness of the knowledge in any country but his own.

He dwelt on its advantage to mechanics, in enabling them to have a common standard where there is now so much confusion and arbitrary method of measurement, as in screws, taps, dies, etc., both in government and private shops..

Mr. J. P. Putnam continued the subject by reading a communication on the advantages of the system, and the means that had been taken to introduce it into various countries. That decimal division of weights, measures and money, is of the first importance in computation is shown by the praise generally bestowed on the federal currency; and that engineers share in this opinion may be seen by their using decimals of a foot where they can, although, by so doing, they are at variance with the general practice of the community.

The real difficulty is not with the proposed system, but with making the change. The cost of such a revolution, affecting so large a proportion of the transactions of life, must be enormous; but it is equally true, if not quite so obvious, that it is costing enormously to keep up the present confusion. It is already used in the mint and on the coast survey; men of science have used it for many years; it is used by analytical chemists, and will soon be used by many architects and constructors all over the country. To accomplish its introduction concerted action is necessary.

In the metric system, the weight and dimensions of every material thing, — whether solid, liquid, or gaseous, — whether on land or on water, — whether in the earth or in the heavens, — and whether determined by the scale, plummet, balance, barometer, or thermometer, — are ascertained by a method absolutely uniform, entirely simple and equally suitable to the use of all mankind, — resting upon a single invariable standard of linear measure, with multiples and submultiples, like those of our monetary system, — exclusively decimal, with appropriate names, similar in all languages — and itself secure against the possibility of change, or loss through carelessness, or accident, or design, by being constructed on scientific principles, and copied for distribution among the different nations of the

world. The standard unit of length, the metre, is the ten millionth part of the quadrant of the meridian, equal to very nearly 39.37 English inches.

NEW METHODS OF TOPOGRAPHICAL SURVEYING.

January 13, 1876. Prof. E. C. Pickering made a communication on some new methods of topographical surveying among mountains, devised by himself, as distinguished from the old method of trigonometrical survey, which is very expensive as well as inaccurate, and from the plane table, which answers very well for the determination of a few points.

He exhibited a new instrument, with various modifications, for use among the mountains. His object was to dispense with the graduated circle, and its bulky and heavy stand, and to be able to make accurate observations without the necessity of ascending the mountains, thus saving much time, labor and expense. He brought to the notice of the meeting three different methods, each having its special applications.

The first was a new stadium, as a substitute for the one commonly used in the coast survey and elsewhere, which requires the services of two persons, and which is also inaccurate. He uses an ordinary small and portable telescope, lightly but firmly mounted, having a plane glass mirror in front of the object glass; by placing this mirror at the proper angle, the two images of an object are made to coincide. Two positions being taken on the same line, at right angles to the object seen, the measurement of the different angles from these different points enables the observer to measure the distance with a great degree of accuracy.

This instrument, used for measuring horizontal distances, being made to turn 90° on its longitudinal axis, may then be employed for measuring heights. He uses a good level firmly attached to it, and a spider-line micrometer, or eye-piece, containing a divided scale. It is practically, therefore, a zenith telescope, without vertical circle or heavy mounting, but with a

rigid connection between the level and the instrument. Its liability to error is very small, and its use easy and satisfactory.

The third form of apparatus was for working out details, after certain main features had been determined by other means; it was specially valuable for making contour maps, which by ordinary processes are difficult and expensive. His device was a modification of the camera obscura, easily transported and managed. He explained how, by this simple apparatus, the height and velocity of clouds may be determined, the distance of a thunder-cloud, and the velocity of sound.

Attention was drawn to the simplicity and efficacy of these instruments, which would so diminish the cost, and increase the accuracy of topographical surveys, that no State need be deterred from authorizing such survey on the ground of the great expense of the topographical work.

NEW WIND VANE.

January 27. Prof. Pickering described a new form of wind vane, an invention of Mr. W. H. Pickering, now a student at the Institute.

It consisted of an ordinary vane, which had attached to the base of its pivot-socket two arms inclined downwards, one on each side of the vane. To the left hand arm was attached a ball, and to the right a piece of ground glass, of such a size that when viewed from the front it would present the same amount of surface as the ball, both about as large as the letters denoting the points of the compass. The object is to show the direction of the wind under all circumstances, especially when a person in the line of the wind might be unable to tell whether it was north or south, east or west; when the ball appears to the right of the pivot the vane is pointing toward you, and when to the left, away from you. The ball is the object judged by, as the glass would be invisible at a short distance, the use of the last being to counterbalance the weight of the ball and to counteract the action of the wind on it. The improvement is a very cheap one, and can be easily applied to any vane now in use.

INSTRUMENT FOR DRAWING CURVES.

Mr. John M. Batchelder, of Cambridge, sent for exhibition a new instrument, devised by himself, for drawing curved lines, such as are ordinarily made by the French curves.

A diagram of the various and graceful curves which may be drawn by this instrument was exhibited. The opinion was expressed that the flexibility of the steel bands was such that extreme care would be necessary to insure accuracy.

Mr. Moore spoke of the importance of preserving in some way the diagrams made in illustration of the papers read before the Society, in many cases indispensable for the permanent value of communications.

DIFFERENTIAL COMPASS.

February 10. Mr. S. W. Holman, a student of the Institute, in the Department of Physics, presented in behalf of the inventor, Mr. George Iles of Montreal, a new form of mariner's compass, called a "Differential Compass."

The instrument was designed to detect variations of the compass needle, due to the disturbing action of iron ships, and to give the mariner a means of correcting this error at any time, thus obtaining the magnetic north.

After explaining the effect of the iron mass of a vessel on the compass, illustrating the action by magnets, he described the model.

It consists of two compound needles pivoted one above the other. The upper needle is made up of a series of bundles of small steel magnets, held between two long strips of aluminum; the bundles are arranged with their like poles pointing in the same directions, the north pole of one bundle being placed toward the south pole of another. As each small bar magnet can be much more intensely magnetized in proportion to its bulk than a larger one, we can obtain by this arrangement a much more intensely magnetized needle than with an ordinary steel bar. The lower compass needle is an ingenious arrange-

ment of similar small steel magnets across a bar of aluminum, like poles being all upon the same side of the bar. In this way is produced a compound needle, which sets with its length east and west; when pivoted one above the other, the needles set at right angles.

If a piece of soft iron, or an attractive magnetic pole, be introduced into any quadrant near the needles, the quadrant is diminished to an acute angle. Upon this fact is based the method of determination of the deviation of the compass and its compensation. The conclusion of the inventor was that any disturbing mass at any distance would cause the needles to deviate toward each other in some quadrant, forming an acute angle there; this acute angle was to be rendered a right angle again by the repellant pole of a compensating magnet under certain prescribed conditions.

Mr. Holman showed that, from experiments performed by him on this compass in the laboratory, the action of disturbing forces at a distance was not as Mr. Iles had expected,— that an acute angle was produced only when such force was at a small distance from the needle as compared with the length of the small magnets composing these needles,— and that the compass failed to show any variation from a right angle between its needles, when a disturbing magnet had moved them both through a very large angle from a true position.

He then showed, upon theoretical grounds, the reason for these two actions at different distances, making evident in this way the fallacy of the instrument, which had acquired a wide reputation.

NEW SYSTEM OF RIFLING CANNON.

March 9. Prof. E. L. Zalinski, U. S. A., read a paper, illustrated by numerous diagrams and models, on a new system of rifling heavy guns, devised by Mr. S. P. Ruggles, a member of the Society.

The following extracts embrace the principal points in the paper.

He sketched briefly the object of rifling guns, the various

kinds of rifled projectiles, the principal methods in use at the present time, and the arguments of advocates of the uniform and variable pitch or twist of rifling.

The object of rifling guns is to give projectiles, not spherical, a rotary motion, which gives greater range and accuracy, and to impart the maximum projectile force to the shot with the minimum strain upon the gun. These projectiles are known as expansive, compressive, and flanged.

The expansive class are made smaller than the bore to facilitate loading, being used most frequently in the muzzle-loading cannon. The pressure of the powder-gas expands a soft metal cup or base so as to cause it to fill the grooves and rotate the projectile.

The compressive class are made larger than the bore, and used with breech-loaders, and are made to take the rifling by being compressed. They are made of iron or steel, with a thin soft metal coating, usually a compound of lead and tin. This system is gradually being abandoned, as it strains the gun, and reduces the velocity and accuracy.

The flanged class are made with flanges which correspond in position and inclination to the grooves of iron lined on the bearing side with a softer metal. While this class has given good results as to accuracy, range, and penetration, they strain the gun and the flanges are liable to break; they can not be used with a variable twist; they are used, however, by most European nations.

Mr. Ruggles's plan of rifling cannon and projectiles was shown by a model. It contains sixteen grooves of a serrated shape. The grooves used in United States cannon are rectangular, this Mr. Ruggles claims is unnecessary, as only one side of the groove is subjected to any strain or bearing in firing; consequently a number of serrated grooves, each having the same effective bearing surface as the rectangular groove, can be cut in the bore, doubling thereby the bearing surface without weakening the gun.

The projectile has an expansive sabot of soft metal, which is forced into the grooves by the powder gas, which thus gives the

required rotary motion. From this kind of groove the sabot is able to expand, fitting closely the bore at every point, utilizing the entire force of the powder, and preventing the escape of the gas, which is not the case with the service groove. Around the front of the projectile, near the junction of the cylindrical and conical portions, is a soft metal hoop, which is to be expanded by the gas that must pass the base sabot at the first moment of explosion; this will cause it to expand sufficiently to centre the front end, although it may not have fitted the grooves. This band is put on loosely, so that it may turn.

Opinions differ as to the rate and kind of twist that should be given to rifling. There are two kinds of twist used, uniform and varying. The uniform twist is one which imparts the required rotary velocity upon starting the projectile; the increasing variable twist is one which causes the projectile to move straight forward at first, and then gradually acquire its ultimate rotary velocity at the muzzle.

Mr. Ruggles proposes to use an increasing twist, and considers that one based upon the law of gravitation will give the best results. By an ingenious device he has made the twist an exact copy of the law, as to progressive increments of pitch, giving the projectile one revolution in travelling the first 48′ of its flight.

Remarks by several experts in the science of gunnery and projectiles added to the interest of the meeting.

DEVELOPMENTS IN STEAM ENGINEERING.

March 23. Prof. Channing Whitaker read a paper on some "New Developments in Steam Engineering."

De Pambour thought that saturated steam expanding in a cylinder followed the laws of Mariotte and Gay Lussac, that the steam remained saturated during the expansion, and that the weight of steam in the cylinder was constant throughout the expansion; we now know that these ideas are inconsistent with each other.

Mariotte's law is that the pressure is inversely proportionally to the volume; this law he represented by a diagram on the board.

He gave the results of Regnault's, Rankine's, Zeuner's, Fairbairn's, and Tate's experiments, as represented by diagram curves.

After Dr. Joule had determined the mechanical equivalent of heat, it was ascertained that some of the steam in the cylinder would be condensed during expansion if no heat was communicated to it during that time, and hence, it was believed that the expansion line, instead of being a curve of a constant weight of saturated vapor, was a curve of a constantly decreasing weight of vapor. Rankine called this an " adiabatic " curve, and this has been generally accepted by engineers as the one coming nearest to that according to which steam should expand in the cylinder of an engine. It is supposed that the steam neither receives heat from, nor imparts heat to, any other substance during the expansion, but that as much heat as is necessary for the purpose is converted into the work done during expansion. The heat converted into this work is then obtained from the steam which is expanding, and a portion of it is therefore condensed, and the curve is one of a decreasing quantity of saturated vapor.

Prof. Whitaker stated that it is by no means certain that steam in a cylinder should be expected to expand along an adiabatic curve. The supposition that the steam neither receives heat from, nor imparts heat to, any other substance during expansion, is an untenable one, and the conclusion is in error to the extent that it is affected by this supposition. He laid before the meeting some facts which led him to believe that the conditions of ordinary expansion are not those of the adiabatic curve.

In almost all cases, indicator diagrams taken from unjacketed engines using saturated steam expansively, show a greater increase in the weight of steam during expansion than if the steam had expanded along a Mariotte's curve. During the winter of 1874–75 many experiments were made by the students in the Mechanical Engineering Laboratory of the Institute bearing upon the question of condensation and re-evaporation in the cylinder. He gave an abstract of the thesis of Mr.

J. H. Head, from which it appeared that in unjacketed cylinders the co-efficient of expansion of saturated steam, established theoretically by Rankine as $\frac{1}{9}^{0}$, is incorrect in ordinary practical usage; the co-efficient is not constant, varying in different engines, and even at different cut-offs in the same engine.

Two principal reasons have been assigned for the increase in the weight of steam in the cylinder during expansion: — leakage, and re-evaporation of water which entered as steam and condensed against its cool walls during the early part of the stroke, the re-evaporation being produced by heat returned to the steam during expansion by the walls of the cylinder. As to the first, it seemed to him reasonable to suppose that in most cases at least as much steam will leak out of as into the cylinder during the expansion. He thinks the results more likely due to condensation and re-evaporation.

BLOOD GLOBULES OF MAN AND MAMMALIA COMPARED.

April 6. Dr. Ephraim Cutter exhibited micro-photographs of the blood of man and of some of the mammalia, taken by himself.

The object of his researches was to ascertain what ground, if any, medico-legal experts had for saying that they could distinguish the blood of a child from that of an adult, or that of man from that of any other mammal.

The images thrown on a screen by the calcium light can be measured directly, and any observer can decide for himself whether such discrimination is possible, as size is the only morphological element of the red blood corpuscle taken into account by such experts.

The averages of the measurements were as follows:

Man	1-3100	to 1-3200	of an inch.
Dog	1-3200		" " "
Squirrel	1-3600		" " "
Rat and Rabbit	1-3400		" " "
Deer	1-3500		" " "
Ox	1-3900		" " "
Pig	1-4028		" " "
Horse	1-4200		" " "
Sheep	1-5600		" " "

All were taken with the same $\frac{1}{50}$ objective of Tolles at a distance of 26 inches, and reduced upon the glass positives at the same distance from the camera. The powers used are very much higher than have ever before been employed in microphotography.

Whether such small differences could be of any value in legal medicine, especially as in the same specimen the size varies considerably, he left for others to determine.

He also exhibited the appearances presented by diseased blood, in the various stages of consumption, showing characteristic changes in the outlines, appearance, and contents of the globules.

Dr. Cutter exhibited an invalid chair of his invention, in which all the parts have an independent motion in a vertical plane, corresponding to the movements of the natural divisions of the body.

Mr. H. P. Langley read a paper on windmills, and some of the wasted forces of nature. He described a cheap machine of his invention, useful for pumping and other domestic purposes.

ELECTRIC RAILWAY SIGNALLING.

April 27. Mr. William Robinson read a paper on his system of "Wireless Electric Railway Signalling, and the prolongation of batteries" — illustrated by a working model.

His invention shows that the intricate and expensive system of line wires is unnecessary, and that excellent conductors are found in the ordinary rails of the track, resting on the ties in the usual manner and without insulation, disproving the generally received opinion that the electric current would be speedily lost by passing to the earth, especially in wet weather, unless perfect insulation is secured. He gave a sketch of the various attempts to use the rails as conductors, from an English patent in 1848, to his own invention, which would hardly be intelligible without the diagrams.

He also read a paper on his new method of prolonging the

duration of batteries, and gave what he believed to be the explanation of the facts.

MINING LABORATORY OF THE INSTITUTE.

Prof. Richards read a paper on the Mining Laboratory of the Institute, comparing its present with its former condition. In the improvements introduced, the idea has been constantly in mind that the Institute requires real machines, and not toys, to work on a small scale; he believes that any ore susceptible of washing can be practically treated in this laboratory. It connects the school practically with the mining interests of the country, by sending out students capable of putting into successful operation machines they are familiar with. It protects the public from imposition, and private individuals from delusive hopes of a fortune, by establishing a criterion of just and true treatment by disinterested and able experimenters. The future is full of promise.

EXPERIMENTS ON SOUND.

May 11. Mr. William W. Jacques, a student in the Physical Department of the Institute, read a paper, illustrated by diagrams and apparatus, on some new experiments on Sound made by himself.

They consisted of three series: the first was made for the purpose of testing the law of inverse squares; the second to show that the principles of Fresnel and Huyghens, announced for the ether waves, could be applied to waves of sound; and the third, for the purpose of measuring the velocity of sounds of considerable intensity.

There is every dynamical reason for believing that the intensities of light, heat, and sound diminish as the reciprocals of the squares of the distances from their origins. That this is true of light and heat has been demonstrated experimentally; his experiments proved that this law applies also to sound, the observed and calculated results agreeing almost exactly.

There seems to be no *a priori* reason why the principles of Fresnel and Huyghens should not be applied to our atmosphere, and the experiments of Mr. Jacques on the diffraction of sound show that they may be so applied. From his data we may calculate the length of a sound wave, the velocity of sound, and, in short, all of the quantities dependent upon the velocity of sound as well as acoustic quantities analogous to the optical quantities deduced from the diffraction of light.

Many eminent mathematicians and physicists have raised questions as to whether the velocity of sound is not affected by its intensity and pitch, by barometric pressure, hygrometric state, and by other supposed causes. Mr. Jacques's experiments had for their object the measurement of the velocity of sound near the mouth of a cannon. His method consisted of an automatic measurement of the velocity between the members of a series of membranes, placed at different distances from the source of sound, by causing the sound, as it passed each membrane, to register its passage, by means of suitable electric connections, on a chronograph. The experiments were carried on at Watertown arsenal by means of a six-pound cannon. He carefully described the manner of conducting the experiments, which showed that the velocity of sound in the vicinity of a gun is greater than at a distance, by several feet. This is in accordance with theory. The method, when perfected, will probably furnish the most accurate results of the velocity of sound yet obtained.

NEW FORM OF PLANE TABLE.

Prof. Pickering exhibited a simple and inexpensive form of plane table. He called attention to the gradual change in the instruments used by surveyors, the plane table gradually taking the place of the compass. The principal obstacle to its general use is its expense, which, as ordinarily made, is not less than that of a transit, amounting sometimes to nearly three hundred dollars. Its weight, also, is so great as to render its use diffi-

cult among the mountains, and the accurate fitting of some of the parts renders them very liable to injury.

He described and exhibited his instrument, which can be furnished for the sum of fifteen dollars. The cost of the proposed surveys of this and other States may be materially reduced, since the expense of the topography is generally a serious difficulty, and this could be very much lessened if large numbers of competent observers, like the Institute classes, could be provided with inexpensive instruments.

TELEGRAPHING MUSICAL SOUNDS.

May 25. Prof. A. Graham Bell read a paper, illustrated by several experiments, on "telephony" or the telegraphing of musical sounds.

It has long been known that an electro-magnet gives forth a sound when it is suddenly magnetized or demagnetized. When rapidly produced the effect upon the ear is that of a musical note. The discovery of galvanic music by Page in 1837 led inquirers in different parts of the world, almost simultaneously, into telephonic research.

As his researches will be published in full elsewhere, a brief abstract only of some of the principal points will be given here. [Proc. Amer. Acad. of Arts and Sciences. Vol. XII.

In the autumn of 1874, Prof. Bell discovered that the sounds emitted by an electro-magnet under the influence of a discontinuous current of electricity are not due wholly to sudden changes in the magnetic condition of the iron core (as heretofore supposed), but that a portion of the effect results from vibrations in the insulated copper-wires composing the coils. An electro-magnet was arranged upon circuit with an instrument for interrupting the current, — the rheotome being placed in a distant room, so as to avoid interference with the experiment. Upon applying the ear to the magnet, a musical note was clearly perceived, and the sound persisted after the iron core had been removed. It was then much feebler in intensity,

but was otherwise unchanged, — the curious crackling noise accompanying the sound being well marked.

The effect may probably be explained by the attraction of the coils of the wire for one another during the passage of the galvanic current, and the sudden cessation of such attraction when the current is interrupted.

Very striking audible effects can be produced upon a short circuit by means of two Grove elements.

Loud sounds are emitted by pieces of iron and steel when subjected to the attraction of an electro-magnet which is placed in circuit with a rheotome. Under such circumstances, the armatures of Morse-sounders and Relays produce sonorous effects. He has succeeded in rendering the sounds audible to large audiences by interposing a tense membrane between the electro-magnet and its armature. The armature in this case consisted of a piece of clock-spring glued to the membrane. The instrument was connected with a parlor organ, the reeds of which were so arranged as to open and close the circuit during their vibration. When the organ was played the music was loudly reproduced by the telephonic receiver in a distant room. When chords were played upon the organ, the various notes composing the chords were emitted simultaneously by the armature of the receiver.

The simultaneous production of musical notes of different pitch by the electric current, was foreseen by him as early as 1870, and demonstrated during the year 1873. Elisha Gray, of Chicago, and Paul La Cour, of Copenhagen, lay claim to the same discovery. The fact that sounds of different pitch can be simultaneously produced upon any part of a telegraphic circuit is of great practical importance; for the duration of a musical note can be made to signify the dot or dash of the Morse alphabet, and thus a number of telegraphic messages may be sent simultaneously over the same wire without confusion by making signals of a definite pitch for each message.

If the armature of an electro-magnet has a definite rate of oscillation of its own, it is thrown bodily into vibration when the

interruptions of the current are timed to its movements. For instance, present an electro-magnet to the string of a piano, it will be found that the string which is in unison with the rheotome included in the circuit will be thrown into vibration by the attraction of the magnet.

All the effects noted above result from rapid interruption of a voltaic current, but sounds may be produced electrically in many other ways.

The Canon Gottoin de Coma, in 1785, observed that noises were emitted by iron rods placed in the open air during certain electrical conditions of the atmosphere; Beatson produced a sound from an iron wire by the discharge of a Leyden jar; Gore obtained loud musical notes from mercury, accompanied by singularly beautiful crispations of the surface during the course of experiments in electrolysis; and Page produced musical tones from Trevelyan's bars by the action of the galvanic current.

When an intermittent current is passed through the thick wires of a Ruhmkorff's coil, very curious audible effects are produced by the circuit.

When a voltaic battery is common to two closed circuits, the current is divided between them. If one of the circuits is rapidly opened and closed, a pulsatory action of the current is occasioned upon the other. All the audible effects resulting from the passage of an intermittent current can also be produced, though in less degree, by means of a pulsatory current.

When a permanent magnet is caused to vibrate in front of the pole of an electro-magnet, an undulatory or oscillatory current of electricity is induced in the coils of the electro-magnet, and sounds proceed from the armatures of other electro-magnets placed upon the circuit.

The effect was much increased when a battery was included in the circuit. In this case, the vibration of the permanent magnet threw the battery-current into waves. A similar effect was produced by the vibration of an unmagnetized tuning-fork in front of the electro-magnet. The vibration of a soft iron

armature, or of a small piece of steel spring no larger than the pole of the electro-magnet in front of which it was placed, sufficed to produce audible effects in the distant room.

Electrical undulations can be produced directly in the voltaic current by vibrating the conducting wire in a liquid of high resistance included in the circuit, as water, dilute sulphuric acid, or saturated solution of salt.

Sullivan discovered that a current of electricity is generated by the vibration of a wire composed partly of one metal and partly of another; and it is probable that electrical undulations were caused by the vibration. The current was produced so long as the wire emitted a musical note, but stopped immediately upon the cessation of the sound.

Although sounds proceed from the armatures of electro-magnets under the influence of undulatory currents of electricity, he has been unable to detect any audible effects due to the electro-magnets themselves.

The telephonic effects described above are produced by three distinct varieties of currents, which he terms respectively intermittent, pulsatory, and undulatory. Intermittent currents are characterized by the alternate presence and absence of electricity upon the circuit; pulsatory currents result from sudden or instantaneous changes in the intensity of a continuous current; and undulatory currents are produced by gradual changes in the intensity of a current analogous to the changes in the density of air occasioned by simple pendulous vibrations.

The experiments were novel and successful, and were witnessed by a large audience.

The meetings were then suspended for the season.

Mr. George W. Hammatt was elected an Associate Member. Messrs. A. T. Hall, George W. Pratt, and Thomas W. Pratt, have died during the year. Eight members have resigned, and four have been dropped for non-payment of fees. The list now comprises 63 life and 185 associate members.

SCHOOL OF INDUSTRIAL SCIENCE.

The attendance at the School of Industrial Science for the year has been 299, as follows: Resident graduates, 11; Regular students of 4th year, 43; of 3d, 43; of 2d, 30; of 1st, 66;— Students not candidates for a Degreee: 4th year, 15; 3d year, 14; 2d year, 21; 1st year, 19; Architectural Students, 23; Students in Practical Design, 25, of whom 12 were females— total 299, of whom 8 were graduates of other Institutions. Of these about two-thirds were from Massachusetts, principally from Boston and its vicinity; — from other New England States, 22; viz.: from Maine, 6; New Hampshire, 6; Connecticut, 5; Rhode Island, 4; Vermont, 1. From other States, there were from New York, 9; Ohio, 8; Illinois, 7; Indiana, 3; Pennsylvania, Iowa, Kentucky, Minnesota, California, 2 each; New Jersey, Michigan, Virginia, and District of Columbia, one each; from Japan, 4; from the Hawaiian Islands, Canada, and New Brunswick, one each.

Thirty-four professors and teachers have been connected with the school, and several advanced students have rendered assistance in the various laboratories and in surveying. The fees rom students have amounted to about $46,000.

The class in the School of Design has been full, and the work has been entirely satisfactory.

The Lowell Free Courses for the year were as follows:

I. *General Chemistry.* Twenty-four laboratory exercises, of two hours each, on Wednesday and Saturday afternoons, at 2½ o'clock, by Professor Nichols, beginning Nov. 3.

II. *Qualitative Analysis.* Twenty-four laboratory exercises, of two hours each, on Wednesday and Saturday afternoons, at 2½ o'clock, by Professor Nichols, beginning Nov. 3.

III. *Philosophy.* Eighteen lectures for beginners, on *Kant's Critique of Pure Reason*, on Monday and Wednesday evenings, at 7½ o'clock, by Professor Howison, beginning Nov. 8.

IV. *Physiology and the Laws of Health.* Eighteen lectures on Tuesday and Friday evenings, at 7½ o'clock, by Professor Kneeland, beginning Nov. 9.

V. *Heat and its Applications.* Eighteen lectures on Tuesday and Friday evenings, at 7½ o'clock, by Professor Ordway, beginning Nov. 9.

VI. *Perspective and the Perspective of Shadows, with Applications.* Eighteen lessons on Wednesday evenings, at 7½ o'clock, by Professor Ware, beginning Nov. 3.

VII. *Light in its Relation to Color.* Eighteen lectures on Wednesday and Saturday afternoons, at 3 o'clock, by Professor Cross, beginning Jan. 12, 1876.

VIII. *Elementary German.* Eighteen lessons on Monday and Wednesday evenings, at 7½ o'clock, by Professor Otis, beginning Nov. 22.

These were open to both sexes over eighteen years of age; applicants to apply in their own hand-writing, stating age, occupation, and previous preparation. These courses are always well attended by persons desirous of substantial teaching, and having a serious purpose of improvement.

MEETINGS OF THE CORPORATION.

The Corporation has held nine meetings during the year.

At the meeting of Oct. 13, 1875, it was voted to establish a dining room for the students in the gymnasium building.

At the meeting of May 10, 1876, it was voted that the Committee on the School be authorized to cause a laboratory to be constructed for advanced instruction in Chemistry and allied subjects to women, provided that the funds are contributed by the "Women's Educational Association."

At the same meeting the Committee were authorized to open such departments of the school as they see fit, to advanced special students of either sex, or to special classes, where it can be done without interfering with the regular work of the school—on payment of certain fees.

At the meeting of June 7th, it was voted to confer the Degree of Bachelor of Science on the following students who had complied with all the requirements therefor:

Thos. Aspinwall, Jr.	Brookline	Civil Engineering.
T. W. Baldwin, A. B.	Bangor, Me.	" "
Joshua B. F. Breed	Louisville, Ky.	" "
Harry T. Buttolph	Buffalo, N. Y.	" "
Fred. K. Copeland	Winchester	" "
John R. Freeman	Lawrence	" "
Frank W. Hodgdon	Arlington	" "
Arthur L. Mills	Everett	" "
Henry Raeder, Jr.	Hyde Park	" "
Henry M. Waitt	Nantucket	" "
Henry B. Wood	Woburn	" "
Charles L. Rich	Morrisville, Vt.	" "
Wm. P. Jewett (72–3)	Cape Elizabeth, Me.	" "
Henry L. Ripley (72–3)	Kingston	" "
Aaron D. Blodgett	Boston	Mechan. "
Clarence L. Dennett	Beverly	" "
Francis E. Galloupe	Lynn	" "
Sumner Hollingsworth	S. Braintree	" "
Alfred C. Kilham	Beverly	" "
Theodore J. Lewis	Philadelphia, Pa.	" "
Chas. T. Main	Marblehead	" "
Chas. F. Prichard	"	" "
Chas. F. Allen	Cincinnati, O.	Mining "
Alfred E. Hunt	Hyde Park	" "
Sam'l James, Jr.	Cambridgeport	" "
Thos. W. Robinson	Chicago.	" "
Theo. E. Schwarz	Boston	" "
Julius H. Susman	"	" "
Walter D. Townsend	"	" "
Wm. P. Atwood	Lowell	Chemistry.
Chas. R. Fletcher	Chelsea	"
Albert H. Low	Boston	"
Chas. N. Waite	Medford	"
Wm. E. Nickerson	N. Somerville	"
Robert H. Gould	E. Cambridge	Metallurgy.
Walter B. Barrows	Reading	Natural History.
Wm. O. Crosby	Washington, D. C.	" "
John B. Henck, Jr.	Boston	Physics.
Silas W. Holman	Framingham	"
Wm. W. Jacques	Newburyport	"
Willis E. Davis	San Francisco, Cal.	Science and Literat'e.
Chas. A. Sawyer.	Chicago, Ill.	" " "

David W. Phipps . . . Boston . . . . . Philosophy.
Robert C. Ware, S. B. . Marblehead . . . . "

The subjects of the Theses, and the abstracts of the same, will be found in subsequent pages.

The progress of the School in the various departments will be found in the reports of the President and Professors.

At the meeting of Aug. 17th, it was voted to approve the plan for the new course in Practical Mechanism proposed by the President, and to construct a one story brick building for that and advanced and organic chemistry, the funds having been contributed by the Charitable Mechanic Association, the Women's Educational Association, and from sources unconnected with the funds of the Institute.

SAMUEL KNEELAND, *Secretary.*

Boston, Oct. 2, 1876.

DEPARTMENT OF PHYSICS.

BOSTON, JAN. 31, 1877.

Prof. J. D. RUNKLE,

President of the Mass. Inst. of Technology.

DEAR SIR:—

My official connection with the Massachusetts Institute of Technology, which has extended over a period of precisely ten years, terminates to-day. I therefore take this opportunity of presenting a statement of the work I have accomplished, and of comparing the condition of the Physical Department and the nature of the instruction with that of ten years ago. At that time instruction in Physics was universally given by lectures and recitations illustrated by experiments and diagrams. A student wishing to pursue this subject further, might aid his instructor in preparing these experiments, and thus become qualified in his turn to deliver the lectures. The first step towards the introduction of a new order of things seems to have been taken by Prof. Wm. B. Rogers, then President of the Institute, and Professor of Physics and Geology. In a pamphlet entitled "Scope and Plan of the School of Industrial Science of the Massachusetts Institute of Technology," published in 1864, the following paragraph headed "Practice in Physical and Chemical Manipulations" occurs on page 23:—

"It will be the object of these exercises to make the student practically familiar with the adjustments and use of the apparatus and agents employed in the more important experiments and processes in natural philosophy and chemistry. With this view, the students, under the direction of their teacher, will be called, by small classes at a time, to execute with their own hands various experiments in mechanics, pneumatics, sound, optics, electricity, and other branches of experimental physics, and to exhibit chemical reac-

tions, to fit up chemical apparatus, to prepare gases and other products, and demonstrate their properties by suitable experiments, accompanying these manipulations, when required, with an explanation of the apparatus used, or of the process or experiment performed."

On page 24 the following paragraph occurs under the heading "Laboratory of Physics and Mechanics": —

"In this laboratory, it is proposed to provide implements and apparatus with which the student may be exercised in a variety of mechanical and physical processes and experiments. Thus he may learn practically the methods of estimating motors and machines by the dynamometer, of experimenting on the flow of water and air, or other gases, and of testing the strength of the materials used in construction. He may become familiar with the adjustments and applications of the microscope; be practised in observing with the barometer, thermometer and hygrometer; and, in a room fitted up for photometry, may learn the mode of measuring the light produced by gas and other sources of illumination, and the value of different kinds of burners, lamps, and their appendages."

This appears to be the first clear statement of the desirability of teaching Physics by the Laboratory method, but owing to the pressure of other business and the lack of means, the matter stopped at this point, and no definite plan was formed for carrying it out.

Accordingly the first instruction in Physics at the Institute was given by the usual illustrated lectures, and this continued to be the case for the two following years. Meanwhile, my appointment in charge of the exercises in Physics led me to consider whether a plan for a Physical Laboratory might not be developed, and, accordingly, in April, 1869, a scheme was offered to the Government of the Institute and printed and distributed among them, under the title "Plan of the Physical Laboratory."

This plan was carried out the following autumn, and has been in operation ever since without sensible change, except in extending its scope. In fact, out of sixteen experiments published in 1870 all but one or two are still in use without alteration.

The cost of establishing this Laboratory was exceedingly small. The argument used was, "this is an experiment and may not prove a success, therefore we will begin on a small scale, and if it accomplishes its end the public will at once appreciate its value, and it will not be difficult to obtain a liberal support, while if unsuccess-

ful, the loss to the Institute will be small." Here, if anywhere, the mistake was made; it accomplished far more than its projectors anticipated, but the public, seeing how much had been accomplished with so little, supposed that no more was needed. The great need of the Physical Laboratory at the present time is an independent endowment, by which, as regards apparatus, it may be placed on an equal footing with other Laboratories since established. Instead of an original expenditure of several thousand dollars, the cost to the Institute was little beyond that of fitting up the room adjoining the lecture-room with tables, and gas and water fixtures, and most of this was done by those already connected with the Institute. The apparatus was largely constructed in a similar manner, at small cost, and without regard to looks, the working being almost the sole consideration. Notwithstanding these adverse circumstances, the work of the Laboratory has been continually increasing. The space first provided proving insufficient, a portion of the long room at the end of the building was added, and soon after the whole of this room was appropriated to this purpose. Two large rooms, one nearly a hundred feet in length, were thus devoted to Laboratory work. But, as many small rooms were needed rather than a few of large size, two alcoves were partitioned off from the main room, one devoted to a chemical store-room, and the other fitted with tools for a workshop. Recently, a partition has been run along one side of the large room, by which small rooms are formed for electrical measurements, photometry and optical experiments requiring the exclusion of a portion of the light. The use of a portion of the closet adjoining the physical lecture-room has also been granted for a battery room, and for photographic work, and last year the room to the east of the front door has been darkened, so that it may be used for spectroscopic and other similar work. Notwithstanding this large amount of space, it is not of the kind best adapted to a Physical Laboratory. Accordingly last summer I presented a plan by which the same facilities could be obtained with a much more economical arrangement of space. I proposed that the present rooms should be given up to lecture-rooms, or some of the other purposes to which they are admirably adapted, and that a block of three small dwelling houses should be con-

verted into a Physical Laboratory. One of these could be leased to the Director, and the other two would contain the large number of small rooms especially required for this work. Among the numerous advantages of this plan are the economy, considering the additional space gained, the means of erecting stone piers to secure steadiness for delicate instruments, the light for spectroscopic and photographic work, the easy access to the ground for out-door experiments, the comparatively unobstructed view for astronomical or meteorological observations, and the convenience for undertaking experiments requiring power.

The work of the Laboratory may be divided into three classes: that for the regular students, additional courses, and original investigation. The first of these has been fully described elsewhere, in previous reports, in the Catalogues of the Institute, and in the "Elements of Physical Manipulation." The latter work, in particular, gives in detail the work of the Laboratory, and is, in fact, based on the manuscript directions to students in performing their various experiments. It will therefore be sufficient here to state, in a general way, what would be the work of an average student in the third year in the course as now given. The actual experiments differ a little in each case, but the following list shows approximately what is done by every regular student in the third year's Class.

3. *Insertion of Cross-Hairs*, teaching the student to handle delicate objects.

11. *Calibration of Water*, for graduating vessels.

12. *Cathetometer*, measuring the height of columns of liquid.

14. *Spherometer*, measuring the curvature of a lens.

15. *Estimating tenths of a Second*, as in very accurate measurements of time.

23. *Composition of Forces*, illustrating the parallelogram of forces.

25. *Parallel Forces*, measuring their resultant and comparing with theory.

28. *Crank motion*, comparing the relative positions of a piston rod and fly-wheel with that given by theory.

35. *Deflection of Beams*, proving the laws of elasticity.

41. *Borda's Pendulum*, determining the force of gravity by the time of vibration of a pendulum, and measuring its length by (20) *Reading Microscopes.*

45. *Hydrometers*, showing how specific gravity is found.

46. *Specific Gravity Bottle*, for measuring specific gravities.

67. *Absorption Photometer*, measuring the light cut off by glass.

69. *Bunsen Photometer*, for testing the quality of illuminating gas.

76. *Spectroscope*, observing and measuring various spectra and analyzing by the spectroscope various unknown mixtures.

78. *Law of Lenses*, comparing their observed and computed foci.

79. *Microscope*, using various appliances, as reflected and oblique illumination, camera lucida, micrometers, etc.

88. *Opthalmoscope*, viewing the interior of an artificial eye, illustrating various diseases.

92. *Polarized Light*, illustrating a subject otherwise acquired by the student only with difficulty.

96. *Telegraph*, teaching the student to send messages.

98. *Law of Galvanometer*, or currents corresponding to various deflections.

102. *Wheatstone's Bridge*, measuring resistances with apparatus like that used on the Atlantic Cable.

103. *Resistance Coils*, making and testing resistances by the British Association Bridge.

105. *Electromotive Force and Resistance of a Battery*, or a complete test of a galvanic battery.

118. *Force of Magnets*, or their attraction measured at various distances.

125. *Expansion of Liquids*, with various temperatures.

132. *Law of Cooling*, or the connection between time and temperature.

133. *Pressure of Steam*, at various temperatures.

138. *Specific Heat*, measuring first that of water.

145. *Efficiency of Gas Burners*, measuring the number of units of heat generated with a given burner per cubic foot of gas burned.

Since this only represents about fifty hours' work, or two hours a week for twenty-five weeks, the apprehension that all the time would be spent on a few experiments, proved groundless. If the means were sufficient to keep the apparatus in perfect order, there is no reason that this amount of work should not be made the minimum required of all students. Several of the more advanced institutions of learning in this country have already successfully adopted our system in the form in which we use it, and at many others its adoption is strongly desired. The only other plan competing with it, is that in which every experiment shall be very exhaustively treated, which requires a long time to be devoted to each one. This system may have advantages for specialists (though even then I think it should follow that given above), but I doubt its advisability with large classes of students not particularly interested in physics as a profession. As a matter of general culture, the list of experiments detailed above would have greater value than any single experiment, however fully treated. The use of the course here described as a means of culture should not be overlooked, as it is with this object that its introduction into our larger colleges is to be expected. A student accustomed to learn merely from books acquires a new knowledge of physical phenomena, when he himself proves the correctness of theoretical laws by actual experiment. Facts thus learned are also far more readily remembered. An interesting feature of this method of teaching is the rapid improvement, especially with classes who have had no previous laboratory practice. Such a class, during their first hour, accomplish almost nothing, and almost discourage both themselves and their instructor; the next hour shows an improvement, and before many weeks, experiments are readily performed without question, which at first were quite unintelligible to them.

A good test of the character of the instruction, is the relation of teacher to pupil. My own relations, which have always been of the pleasantest character, I ascribe largely to the interest of the classes in their work. They remain beyond the hour, encroach upon their dinner-hour, and frequently ask, and are allowed, to work at other times which they might devote to amusement. With this condition of things disorder is almost unknown, and

they are treated, and I believe regard themselves, as friends and guests, rather than as pupils. Of course the consequence shows itself in a largely increased amount of work, and a saving of much of the nervous wear and tear of a teacher's life.

These remarks apply with still more force to the work of the fourth year, which is largely of a professional nature. The students in Civil Engineering and Architecture devote two hours a week to work in the Physical Laboratory for half of their fourth year. The work during the present year serves as a type of that previously done. This year two students planned and built a truss of a form suitable for a roof, and measured its change of shape under various loads. It finally broke under three hundred pounds, while the bars of which it was formed would not have borne a tenth part of the weight. Others studied the laws of continuous girders, and compared the deflections with those given by theory; others tested a water-motor, measuring the flow, the pressure, the work done, the speed and other elements, and from these computed the efficiency. Others, again, measured the strength of wires, the force required to strip a nut off a bolt, and compared the effect of impact, as in a pile-driver, with a dead weight. In former years, several excellent models of bridges have been built by students, and these are now used for tests of change of form with varying loads and for other purposes.

Several other courses have also been given, mostly to students intending to make Physics their profession. Of these the following may be mentioned: —

Mechanical Engineering. Formerly the mechanical engineers spent four hours a week in their fourth year in the Laboratory. With the establishment of a Mechanical Laboratory this work has been given up, and the course is now given to the students in Physics only. It includes various mechanical measurements, as flow of water, strength of materials, velocity of shafting, friction and power (Phys. Manip., II, pp. 109–138).

Lantern Projections. To students in Physics only. The various methods of using the lantern as a means of instruction (Phys. Manip., II, pp. 212–253). Last year, when several students in the fourth year were devoting themselves to Physics, this course was supplemented by some exercises which proved most successful

and useful. Some lectures were given by these students to pupils of some of the neighboring private schools, and illustrated by the lantern and the other lecture apparatus of the department. Thus our students acquired the very best experience to fit them as teachers. The course in Lantern Projections has sometimes been given by Prof. Cross, in connection with his own lectures.

Geodesy. Last year, finding that the students in Civil Engineering received little instruction in this branch of higher surveying, a course of lectures was given to the older students on geodesy and topography, with especial reference to the Geological Surveys now under consideration in many of the United States.

Practical Astronomy. This course, which has been given for the last two years in the form of lectures, promises, by its adoption, an excellent opportunity to some college, provided with the necessary instruments, for the establishment of an Astronomical Laboratory (Physical Manip., II, pp. 166–212).

Photography. This course, originally given by Mr. Whipple, is now given by Prof. Cross to students in Physics only.

Advanced Physics. One of the most successful courses for the special students in Physics is that bearing this name. The form of each exercise is that of a scientific meeting, different students being selected in turn as secretaries. The advantages of a student's society are attained, while the objections of irregular attendance, and that the work would fall mainly on two or three members, are obviated by requiring from all, attendance and the presentation of papers. Each student in turn presents papers, often illustrated by experiments, either on some original work, or a review of some recently published research, or of the latest scientific periodicals. Many of the standard researches in physics have been thus presented, and other matters of value to every scientific man, such as the character of various scientific societies and periodicals and other similar matters. This, with the lectures referred to above, qualifies each student to express himself clearly and composedly before an audience.

For the past two years instruction has been given in the Physical Laboratory to the students of the Boston University, with results highly satisfactory to us. The laboratory course has thus been successfully tested with a class whose previous preparation

has been literary rather than scientific. The income derived could, moreover, have ill been spared in maintaining the Laboratory.

The great object to which my work for these last ten years has been directed, has been original investigation. This is the real goal to which the attention of a student in the Physical Laboratory is directed. The value of the course in physical manipulations is largely that it teaches a student to think for himself, and prepares him with methods by which he may solve any problem for himself experimentally. I have endeavored to impress on all our students in physics the principle that original investigation should be the great aim of every scientific man. In consequence, a great deal has been done in the laboratory that is new, but in many cases there has been neither time nor means for publication. The following articles have been published under the titles here given. Where I have aided the student largely in the work, my name appears; in the other cases the work has been done almost entirely by the student.

* On the Focal Length of Microscope Objectives. By Chas. R. Cross. *Journ. Frank. Inst.*, lix, 401 (June, 1870).

On the Relative Efficiency of Kerosene Burners. By Chas. J. H. Woodbury. *Journ. Frank. Inst.*, xcvi, 115 (Aug., 1873).

The Phonautograph. By Chas. A. Morey. *Amer. Journ. Sci.*, cviii, 130 (Aug., 1874).

I. Foci of Lenses placed obliquely. By Prof. E. C. Pickering and Dr. Chas. H. Williams. *Proc. Amer. Acad.*, x, 300.

II. Light transmitted by one or more Plates of Glass. By W. W. Jacques. *Proc. Amer. Acad.*, x, 389.

III. Intensity of Twilight. By Chas. H. Williams. *Proc. Amer. Acad.*, x, 421.

IV. Light of the Sky. By W. O. Crosby. *Proc. Amer. Acad.*, x, 425.

V. Light absorbed by the Atmosphere of the Sun. By E. C. Pickering and D. P. Strange. *Proc. Amer. Acad.*, x, 428.

VI. Tests of a Magneto-Electric Machine. By E. C. Pickering and D. P. Strange. *Proc. Amer. Acad.*, x, 432; *Electrical News*, i, 14, 54.

VII. Answer to M. Jamin's objection to Ampère's Theory. By W. W. Jacques. *Proc. Amer. Acad.*, x, 445.

VIII. An Experimental Proof of the Law of Inverse Squares for Sound. By Wm. W. Jacques. *Proc. Amer. Acad.*, xi, 265.

IX. Diffraction of Sound. By Wm. W. Jacques. *Proc. Amer. Acad.*, xi, 269.

X. Comparison of Prismatic and Diffraction Spectra. *Proc. Amer. Acad.*, xi, 273 (June, 1875).

XI. On the Effect of Temperature on the Viscosity of Air. By S. W. Holman. *Proc. Amer. Acad.*, xii, 41.

The following articles were published in the Report of the Physical Laboratory for the year 1871–72.

The first four are Reports of the Civil Engineers of the Fourth Year in the course referred to above.

Report upon Experiments on a Queen-Post Truss and its component parts. By Messrs. C. S. Ward and B. E. Brewster.

Measurement of the Angular Deflection of Beams fixed at one end. By Mr. C. F. Allen.

Apparatus for ruling lines with a Diamond. By Mr. C. F. Allen.

Coefficients of Efflux. By Messrs. W. B. Dodge and W. E. Sparrow.

Buoyant effect of a column of heated air from a Bunsen burner. By Mr. C. K. Wead.

Law of Lenses. By Mr. C. K. Wead. The focal length of two or more lenses separately and combined, were here measured.

Photometric Experiments. By Mr. C. K. Wead. The light cut off by 1 to 7 plates of glass was measured, also the absorption of ground glass. Another series of experiments gave the light of an Argand burner with various consumptions of gas.

To find the Refractive Formula (that of Cauchy) for any Substance. By Mr. F. W. Very.

Micro-photography. By Mr. C. S. Minot.

Saccharimetry. By Mr. F. A. Emmerton.

Of the unpublished papers may be mentioned the following: —

On Covering Steam Pipes. By several students, collated by Mr. B. H. Locke.

Magnetization by Frictional Electricity. By Mr. C. K. Wead.

Electricity generated by a Holtz Machine in absolute measures. By Mr. S. J. Mixter.

On the Density of the Earth. By Mr. J. B. Henck, Jr.

Measurements of Plateau's Soap-Bubble Films. By Mr. W. E. Nickerson.

Velocity of Air Currents at various distances from an Air-jet. By several students.

Resistance of Water in Pipes. By several students.

Measurement of curvatures and minute distances by Newton's Rings. By Dr. C. H. Williams.

Law of Vibration of a Tuning Fork. By Mr. S. H. Wilder.

Effect of the Intensity of Sound upon its Velocity. By Mr. W. W. Jacques.

It remains for me to speak of my own work, which I do without hesitation; first, since the reputation of the Institute is largely that of those connected with it; and, secondly, because the intellectual as well as the physical results of my work should be in the possession of the Corporation of the Institute.

As the entire work of building up the Physical Laboratory, making or having made the apparatus, and conducting the exercises has been in my hands, unaided by any assistant, I have had less time than I desired for original investigation. Besides this, I have given all the other courses described above, except where the contrary is expressly stated, and, in addition, have delivered four Lowell Courses of lectures. The first of these, on Sound, was in 1869–70; the second, on Experimental Physics, in 1871–2, gave a class composed mainly of teachers, an opportunity to learn the methods of our Laboratory; the third, on the Applications of Electricity and Magnetism, was given at the Lowell Institute in 1873–4; and the fourth, on Lantern Projections, in 1874–5, was especially designed to aid teachers in using this instrument. In 1872 the laboratory was kept open during nearly the entire summer, and instruction in its methods given to a class of half a dozen gentlemen, mostly Professors of Physics in Western colleges. Although the number of regular students in physics has been small, as was to be expected, there have been every year several special students, some of whom devoted almost all their time to physical investigation. To provide work for them, many of the researches I should otherwise have undertaken myself I have put in their hands, and this proved an additional drain on the limited number of subjects of investigation which will occur to a single individual. My principal work has been the publication of the two volumes entitled "Elements of Physical Manipulation," which embody the experiments performed in the current work of the Laboratory. During the summer of 1869, I accompanied the Nautical Almanac Expedition to Iowa to observe the total eclipse of the sun of August 7th. In 1870, through the liberality of the Government of the Institute, I was enabled to

accompany the Coast Survey Expedition to Spain, to observe the total eclipse of the sun of December 22d. The summer of 1873 was largely devoted to observations, with a new form of polarimeter, on the light of the sky and that reflected and refracted by plates of glass. During the summer of 1876 several thousand observations were taken of the heights of the White Mountains with a micrometer level. The results, which will probably supply the most complete survey yet made of this region, are now in process of reduction. The following list gives the references to the published accounts of these researches, together with the more important of my other published papers: —

Dispersion of a Ray of Light refracted at any number of Plane Surfaces. *Proc. Amer. Acad.*, vii, 478 (April, 1868).

Essay on the Comparative Efficiency of different forms of the Spectroscope. *Amer. Journ. Sci.*, xlv, 301 (May, 1868).

Description of a Machine for Drawing the Curves of Lissajous. *Journ. Frank. Inst.*, lvii, 55 (Jan., 1869).

Plan of the Physical Laboratory. (April, 1869.)

A New Form of Spectrum Telescope. *Engin. and Min. Journ.* (July, 1869).

Report on the Total Eclipse of August 7th, 1869. *Journ. Frank. Inst.*, lviii, 281 (Oct., 1869). Trans. into French in *Les Mondes*, xxi, 573.

Observations of the Corona during the Total Eclipse. *Phil. Mag.*, xxxviii, 281 (Oct., 1869).

Note on the Supposed Polarization of the Corona. *Journ. Frank. Inst.*, lviii, 372 (Dec., 1869).

On the Diffraction produced by the Edges of the Moon. *Journ. Frank. Inst.*, lix, 265 (April, 1870).

Polarization of the Corona. *Nature*, iii, 52 (Dec., 1870).

Spectrum of the Aurora. *Nature*, iii, 104 (Dec., 1870).

List of Observations of the Polarization of the Corona. *Journ. Frank. Inst.*, lxi, 58 (Jan., 1871).

The Graphical Method. *Journ. Frank. Inst.*, lxi, 272 (April, 1871).

Photographing the Corona. *Journ. Frank. Inst.*, lxii, 54 (July, 1871).

On Dispersion, and the Possibility of Attaining Perfect Achromatism. *Proc. Amer. Assoc.*, xix, 62 (Aug., 1871).

The Eclipse of 1870. *Old and New*, iii, 634 (May, 1871).

Report of Observations of the Total Eclipse of the Sun of Dec. 22d, 1870. *U. S. Coast Survey Report*, 1870, 115, 229.

Report on the Physical Laboratory. 1871.

A Geometrical Solution of some Electrical Problems. *Journ. Frank. Inst.*, lxvi, 13 (July, 1873).

Applications of Fresnel's Formula for the Reflection of Light. *Proc. Amer. Acad.*, ix, 1 (Oct., 1873).

Measurements of the Polarization of Light reflected by the Sky and by one or more plates of glass. *Amer. Journ. Sci.*, cvii, 102 (Feb., 1874) ; *Phil. Mag.*, xlvii, 127 (Feb., 1874).

Applications of the Graphical Method. *Proc. Amer. Acad.*, ix, 232 (May, 1874).

Graphical Integration. *Proc. Amer. Acad.*, x, 79 (Oct. 1874).

Mountain Surveying. *Proc. Amer. Acad.*, xi, 256 (Jan., 1876).

Height and Velocity of Clouds. *Proc. Amer. Acad.*, xi, 263 (Jan., 1876).

Comparison of Prismatic and Diffraction Spectra. *Proc. Amer. Acad.*, xi, 273 (June, 1875).

Elements of Physical Manipulation. In 2 Vols. Vol. I, 1873, pp. 225. Vol. II, 1876, pp. 316.

Allow me now to compare the present condition of the Physical Department with that of ten years ago. Then we had only a single room, with a second unfurnished, very little apparatus, and the entire instruction consisted of one course of lectures. Now, besides the lecture-room, we have two large laboratories, one subdivided so as to give five small rooms, and, in addition, rooms for the spectroscope and for photography. The lecture course has been for some years ably administered by Prof. Cross, and a course of lectures on Descriptive Astronomy has been added to it. The apparatus is in good condition, and contains a large collection of slides for the lantern. A large Physical Laboratory has been built up, which now accommodates a hundred students a year. The course has been extended into the fourth year, giving technical experiments to the architects and civil engineers, and to our own students in photography, lantern projections and practical astronomy. Original investigation is encouraged, and numerous articles have been published by our students in the scientific periodicals of the day. The principles on which our work is conducted are few and simple. First, use is of the first importance, appearance, secondary. All our apparatus is based on this fact. Polish and lacquer are dispensed with, and the money saved is expended on the working parts. Secondly, originality on the part of the student is encouraged to the uttermost, and he is taught that, as a scientific man, original research should be his highest aim. Thirdly, there are no secrets in science, and accordingly every aid has been

extended to other institutions desiring to adopt our methods, by giving them the results of our experience.

Of the present needs of the Laboratory the principal one is an endowment to cover running expenses; in this way only can it be placed on a permanent foundation. The apparatus is of the simplest kind, and comprises but few instruments of precision in the modern sense of the term. It has never received the large sum usually expended on original equipment. For the older students, especially in the course in Advanced Physics, a working library of the standard works in physics, and a few of the later scientific periodicals, are much needed. This last need has been in part supplied by the liberality of a friend of the Institute, but where the journals are to be divided among so many departments, each gets but little. Another generous friend has twice given a large sum to the Laboratory, once for a spectroscope, the most powerful ever made at the time of its completion, and, again, by a timely gift, enabled a large sum to be expended on original investigation Several of the most important papers that have issued from the Laboratory resulted from this gift. The Department is also greatly indebted for a most liberal gift for acoustic apparatus. Two large sums have been given for this purpose, and have furnished the lecture course with an excellent collection of instruments to illustrate the laws of sound.

I cannot close this report without an acknowledgement of the aid I have received from you, Mr. President, in bringing our Laboratory into its present state of efficiency. Your confidence in its success from the very beginning, your encouragement and enthusiasm regarding its extension, and the interest you have shown in every detail, have helped, more than we have realized, to such success as we have attained.

My thanks are also due to Prof. Cross, whose work as student, assistant and professor, has been wholly devoted to the interests of our department. To his unwearied efforts the present high efficiency of the lecture course is very largely due.

With hopes that the next decade may witness as great advances as that which is just completed, I remain,

Very respectfully yours,

EDWARD C. PICKERING,

Thayer Professor of Physics.

DEPARTMENT OF PHILOSOPHY.

To the President: —

I have the honor to present the subjoined account of the work done in my department during the past year.

I. WORK WITH REGULAR STUDENTS OF ALL DEPARTMENTS.

During the first half-year, there were given, to the Fourth Year's class, three lectures a week on the Philosophy of Science; to the Third Year's class, two lessons a week on the Rudiments of Political Economy; and to the First Year's class, two lectures a week on the Structure and Analysis of the Sentence.

The course of the Fourth Year's class, on the Philosophy of Science, included discussions of the nature and essential conditions of Science; the distinction between Pure (or Rational) Science and Empirical Sciences; the Classification of existing sciences as belonging to the one or the other of these two heads; the comparative claims of the so-called Pure and Empirical sciences to the character of strict sciences; the exact logical character of the professed "Inductive Logic"; the proper scientific province of all Empirical Investigation; the Observative and Experimental Methods, and their Canons; the restriction of their use to the formation of a Natural History, properly so-called, and their futility as methods of establishing Universal Laws; the formal imperfection of the existing expositions of the Pure Sciences as contrasted with the speculative

truth of their contents; the reduction of the various Mathematical Sciences to one logical system; and the Logic of the Infinitesimal Calculus, with the history and criticism of the several theories of the same.

I take pleasure in reporting the excellent character of the work done by the class upon these subjects. The examination-paper used at the last Semi-Annual is herewith submitted, as indicating better than any general account, such as the above, the nature of the instruction.

FOURTH YEAR. — PHILOSOPHY OF SCIENCE.

SEMI-ANNUAL EXAMINATION, JANUARY 20, 1876.

I.

1. Prove, from the conception of Science as the Ideal of the Reason, that its form consists in the possession by its component judgments, of the three characters of Certainty, Universality, and Unity.

2. In order to establish man's actual possession of *science*, what is it necessary to show? And what, in order to prove that, in any field, he is on the *path* to science, so far as his experience can indicate the path?

3. What is the distinction between Rational and Empirical science? What three other pairs of titles may be given to these groups of human knowledge, and for what reason?

4. Since, by the very conception of Empirical science, it lacks the two most significant characters of the ideal of science, on what rational grounds can we call it science, at all? — what are its claims to scientific character on the ground of certainty, and what on that of universality and unity?

5. Distinguishing between Universality and Generality, state the Final Problem of all empirical science whatsoever. What are the limits of *certainty* in such science? Why does not the process known as Verification change the logical character of empirical science, and raise its method into one of absolute certainty — of real prediction?

6. How many possible Rational sciences are there, and by what titles are they known? Do they actually exist in man's conscious possession? Is the actual form of their exposition consistent with their logical ideal? Why is the number of possible empirical sciences indeterminate? Mention the principal ones thus far developed, in the order (from the highest down) of their degree of scientific developement.

7. Show that Induction, whether in the strict sense or in the modified sense that Mill gives it, is necessarily illusory as a method of certainty.

8. Show that even the introduction of the Principle of Causality

while it substitutes the Deductive for the Inductive form of arguing to the future, fails to bring empirical judgments into the region of certainty.

9. What is the strict province of Mill's so-called Methods of Empirical Science? Into what two Canons are they all at last resolvable? In what natural illusion do these two Canons logically originate?

10. Estimate the Four Methods in respect to comparative strength for determining the problem on which alone they strictly bear.

II.

[Regulars of Departments V, VI, VII, and IX, may omit this part.]

1. State the General Problem of the science *actually* called Mathematics.

2. Give the two grand divisions of this science, with the object of each, and the three subdivisions of the first, with their objects.

3. Distinguish ordinary Algebra from Arithmetic, and Higher Calculus from ordinary Algebra. What different systems of Higher Calculus are actually in existence? What is the distinguishing character of the system called Diff. and Integ. Calculus?

4. By the combination of what two conceptions is the logical justification of this calculus alone possible? What principle alone justifies the neglect of infinitesimals? Does it merely *justify* this?

5. What doctrine regarding the relations between limits is implied in every operation peculiar to the Diff. and Integ. Calculus? To what class of problems is the application of this calculus restricted?

The course to the First Year's class, on the Structure of the Sentence, differed in no material respect from that which has now become habitual in the first half of that year. By a vote of the Faculty after the Semi-Annual, the instruction of this class in the rudiments of Formal Logic was postponed from the second half of the first year to the second half of the third, and this arrangement adopted for subsequent classes. I cordially approve the change. The course of study in logic and cognate branches required of candidates for any degree, will hereafter be as follows: —

First Year, first half, 30 lessons on the Analysis of Sentences.

Third Year, 7 weeks of second half, 21 lessons on Elementary Formal Logic.

Fourth Year, first half, 45 lectures on the Philosophy of Science.

II. WORK WITH STUDENTS OF PHILOSOPHY.

In the department proper of Philosophy, we have had seven students this year — three regular, and four special. Two of the latter were women; and the presence of all four deserves particular mention, as the result of a recent vote of the Government, opening single courses of lectures, in various departments, to students of either sex who might wish to receive instruction without being subject to examination for admission, promotion, or a degree. It is not unlikely that others, and in greater number, may hereafter avail themselves of the opportunity thus afforded; especially, if some public notice should be given of the existence of such courses.

The regular students have continued their historical and critical work upon the modern philosophical systems, following, to such an extent as thoroughness would allow, the course laid down in the catalogue. The year has been occupied, mainly, with a minute study of Kant's *Critique of Pure Reason*, and of Hegel's *Logic*. They have read all the essential portions of these works, and I believe I do not go too far in saying that they have mastered the principles of them. The four special students joined them in their study of that part of Kant's *Critique* known as the *Deduction of the Categories* — its most important and difficult division. The examination-papers used with the regulars during the year, are annexed.

KANT: — CRITIQUE OF PURE REASON.

SEMI-ANNUAL, JANUARY 19, 1876.

I.

1. In what sense does Kant call his principal works *Critiques* of Reason? What does he mean by "criticism" as distinguished from "dogmatism" and "skepticism"?

2. What *historical* connexion is there between Kant and Hume? between Kant and Leibnitz? What is Kant's *logical* relation to these two men respectively? What, to Locke?

3. What innovation did the *Critique of Pure Reason* introduce into the theory of knowing? Show the revolutionary character that Kant

attributed to the innovation, by quoting the substance of his remarks about the "Copernican point of view" in philosophy.

4. What is Kant's prevailing usage, in the *Critique*, in regard to the term *Reason*? In what other sense does he sometimes use it? What does he mean by *pure* reason? In the expressions "theoretical reason," and "practical reason," what still wider (or deeper) sense does he give to the term *Reason*?

5. In what three questions does Kant sum up the whole problem of philosophy? How, in effect, does he answer each of these?

6. What is the purpose of the First Preface to the *Critique*, and what are the successive points brought out in it? Answer the same questions in regard to the Second Preface.

7. On what distinction between the Two Beginnings of knowledge does Kant rest his case against Empiricism? State the distinction, with clearness and fullness. How would you state it in terms of the notions of Sequence and Cause?

8. Has the foregoing distinction any connection with that between Matter and Form, which plays so large a part in Kant's thinking? Justify your answer to this question at length.

9. State Kant's distinction between the *a posteriori* and the *a priori* in knowing. What two other pairs of terms does he use to mark it? What noteworthy difference in his use of the noun *experience* and of the adjective *empirical*? What two meanings given to the adjective *pure* must be carefully discriminated in reading Kant?

10. Starting from the primary distinctions between Object and Subject, and Matter and Form, trace Kant's whole theory of the upbuilding of cognition; show all the elements that he thinks must enter into cognition, the part he supposes each of them to play, and the logical order in which he represents them as acting. Give his criteria for the *a priori* in knowledge, and vindicate, against Hamilton, his doctrine that each of these carries the other and is therefore adequate by itself. Distinguish between Analytical and Synthetical judgments, justify the distinction against the objections of Lewes, show its bearing upon the Problem of Pure Reason, and state that problem in its universal form, giving its three specializations.

II.

1. In how much, with reference to the distinction between Analytical and Synthetical judgments, had Kant been anticipated by others, especially by Locke; and in what consists his contribution to philosophy in connection with this distinction? Illustrate his new view, in connection, particularly, with the Principle of Causality. What new doctrine, referring to this distinction, does Kant establish respecting mathematical judgments?

What are the respective bearings of these two discoveries upon the establishment of the "critical" standpoint?

2. What is your estimate of Kant's attempts, in § 2 and § 5 of his Introduction, to establish our actual possession of some *a priori* cognitions and some syntheses *a priori*? What is the nature, and what the value, of the proofs of these points furnished by the *Æsthetic* and the *Analytic*?

3. Why does the *Critique* contain an *Elementology* and a *Methodology*? Why, an *Æsthetic* and a *Logic*? Compare Kant's view of the twofold in cognition with that of Locke, showing exactly wherein they agree and wherein they differ. Compare Kant's view of Experience with Locke's.

4. Give Kant's "Graduated Scale of Representations," defining its terms as you go on.

5. What does Kant mean by "immediacy" in cognition? State, as comprehensively and as accurately as you can, what the fact of Iutuition *is*, so far as concerns the Object (Thing in Itself). What, in general, is an "Empirical Intuition"? What does Kant mean by "phænomenon"?

6. Distinguish, after Kant, between *Sense*, *The Senses*, *sensation*, and *empirical intuition*. Is either of these, or is *pure* intuition, an intelligible whole? How is it that we speak of them separately, and apparently define them? To what mental process alone are they conceivable? Make a critical estimate of Kant's theory about the "immediacy" of intuition.

7. In what does the *a priori* faculty (or "Form") of intuitions at last consist? Sketch Kant's attempted proof of this, noticing its waverings from the point, and other defects.

8. Why a "metaphysical" and a "transcendental" exposition of the Pure Forms of intuition? Give the exact distinction between them, taking pains to clear up Kant's peculiar use of the word "transcendental"; and explain the peculiar Method of Proof that signalizes the *Critique*.

9. What remarkable ambiguity is there in the Kantian doctrine concerning the Pure Forms of intuition? [What *should* the doctrine be, for exact consistency with the "critical" principle; and what *is* it, as Kant usually and deliberately states it?]

10. Why is there, in the *Logic*, an *Analytic* and a *Dialectic*? What, in the *Analytic of Conceptions*, corresponds to the distinction between the Metaphysical and Transcendental expositions in the *Æsthetic*? Give the "Logical Table of Judgments" as determined by the Categories, and the "Transcendental Table" of the corresponding Pure Concepts (the Categories themselves).

Make any criticisms that suggest themselves to you upon Kant's so-called "Faculty of Conceptions," and show in what sense only are that and its Categories intelligible. In other words, show the truth and the error involved in Kant's view about the Pure in all cognition, whether intuition or conception.

KANT: — CRITIQUE OF PURE REASON.

ANNUAL, MAY 25, 1876.

1. Make the following distinctions according to Kant: — (1) Between General logic and Special logic. (2) Between Pure logic and Applied logic. (3) Between General logic and Transcendental logic.

2. What are the two main divisions of his *Transcendental Logic*, and what is the object of each?

3. To what in the *Æsthetic* does that part of the *Logic* correspond in what Kant makes out his so-called transcendental table of the Pure Categories? What would be the name of this part, in the terminology adopted in the *Æsthetic*? With what purpose does Kant precede his "Transcendental" table of the Forms of Judgment by his "Logical" table?

Show the inconsequence of this step on Kant's part, and its inconsistency with the principle from which he sets out upon his investigation of the Categories.

4. Show clearly the bearing of your last answer upon the claim of Kant's final table to the title of "transcendental."

Illustrate, by accurate examples, all the distinctions contained in the Logical Table of judgments.

5. Point out, with proofs, Kant's misconceptions about the subdivisions of the Four Fundamental Categories, (1) as to their mutual dependence; (2) as to the distinction between Negation and Limitation; (3) as to the professed "Pairs" in the sub-categories of Modality.

6. What is the exact object of the so-called *Deduction* of the Categories? To what part of the *Æsthetic* does this part of the *Logic* correspond, and what name might accordingly be given to it? What difficulty presents itself, on undertaking the *Deduction*, that did not arise in the corresponding part of the *Æsthetic*?

7. Why is this difficulty inevitable, with Kant's general presuppositions? What does its necessary existence prove, not only in regard to his *prime* presupposition, but in respect to his hypothesis of the difference in *kind* between the "two main sources of knowledge"?

8. Give Kant's attempted distinction between the Intuition-Object and the Experience-Object; — between the two meanings of "Nature."

9. What, in the most general terms, is Kant's offered solution of the problem of the *Deduction*? Is the minor premiss of his syllogism valid or not? Give your reasons.

10. In arguing for this minor, what is the special form of treatment that he adopts in his *Prolegomena to any Future Metaphysic*?

11. What is the treatment most prominent in the First Edition of the *Critique*?

12. And what the one most prominent in the Second Edition?

13. Explain Kant's doctrine of the "Synthetical Unity of Apperception," and its supposed bearing upon the problem of the *Deduction*.

14. What equivoque presents itself in Kant's dealing with this "Synthetical Unity"? Which side of the dilemma ought he to assume, to make the said "Unity" valid for the purposes of *Deduction*? Why can he not consistently assume this side?

What is the bearing of the whole situation respecting the "Synthetical Unity" upon the real character of his "transcendental" in cognition?

10. Show the rise of "The Three Ideas" — Absolute Subject, or The Ego; Absolute Cause, or God; Absolute Total, or The World — out of the analytic of the Three Forms of Inference, viz., the Categorical, the Hypothetical, and the Disjunctive.

16. Into what three corresponding parts is Kant's *Dialectic* divided, and what is the line of its movement in each part?

HEGEL.

ANNUAL, MAY 30, 1876.

1. Distinguish and illustrate the Three Attitudes of Thought toward the Objective World.

2. Summarize Hegel's critiques, (1) of Dogmatism, (2) of Skepticism, both Empirical and Transcendental, (3) of Intuitionalism.

3. State the Hegelian distinction between a *Beginning* and a *Principle*. How many possible distinct Beginnings are there in Philosophy, and why? What is Hegel's *First Principle*? Under what conditions only can this be made a philosophic beginning?

4. What are the general divisions of Philosophy, according to Hegel, whence deduced, and what writings of Hegel's correspond to them respectively?

5. What is meant by *Dialectic*? Point out the truth and the defect in Kant's view of dialectic.

6. Illustrate the universality of dialectic, as shown in the processes of the Objective World, (*a*) of Nature, and (*b*) of Spirit — man's works, the institutions of Reason.

7. Illustrate the same as shown in the Subjective World, (1) in the growth of the individual mind, (2) in the History of Philosophy.

8. State Hegel's doctrine of the *Notion* as the unit of empirical thought, and trace the dialectical rise of this doctrine out of Kant's "Analytic."

9. State the doctrine of the Immediacy and the Mediation of the Notion, and show the origin of this from the dialectic of Kant's "Æsthetic and "Analytic."

10. In what element of Hegel's general philosophy does the truth of Kant's "Transcendental Unity of Apperception" and "Ideas of the Pure Reason" come to light? Define this element as thoroughly as you can.

11. What are the exact subject and purpose of the *Logic*? What error in regard to them must be carefully avoided?

12. What is the *Method* of the Logical Process, according to Hegel, and what are its "moments"? Into what parts does the *Logic* divide itself in accordance with this method, taken at its origin in the "moments" of the IDEA?

13. What is BEING, in its total finitude or determinateness, in terms of Absolute Idealism? What is THOUGHT — empirical *thinking* — in terms of the same? And what, in like terms, is REALITY — the Concrete Universal of Being?

14. Discriminate between this doctrine of the ABSOLUTE IDEA and (1) The Pantheism of Spinoza; (2) the Pananthropism of Fichte; (3) the Nihilism of Schelling's earlier writings.

15. Illustrate the dialectical process of the *Logic* by sketching the movement through the first triad — Being, Nought, Becoming.

In addition to the study of Kant's and Hegel's text, the class have completed those portions of Schwegler's *History of Philosophy* which cover the period from Kant to Hegel inclusive, and also the parallel portions of Ueberweg. They have also read Mahaffy's rescript of the *Æsthetic* and the *Deduction*, and considerable portions of Stirling's *Secret of Hegel*. One member of the class made, besides, an extended study of Fichte, reading the English translations of his *Science of Knowledge*, *Sun-clear Statement*, *New Introduction*, *Criticism of Philosophical Systems*, and *Vocation of Man*, together with sundry commentaries and his biography.

Theses have been presented by the class, at various times during the year, on the Life and Writings of Kant, the Influence of Kant upon subsequent Philosophy, and the Derivation of Fichte's System from Kant's.

At the Annual Examination in May last, two of the class — Messrs. David Warren Phipps, of Boston, and Robert C. Ware, of Marblehead, completed their course and received the corresponding degree. The third member passed his examinations, but was prevented from completing his thesis by severe

illness. The subjects of the theses by the two graduates, were "Kant's *Æsthetic*: a Restatement of it, with Criticisms," and "The Historical and Logical Relations between Fichte and Kant." In the former, some new points, of apparently permanent significance, are made in the criticism of Kant. Abstracts of both theses will be found on the appropriate pages of the President's report.

Respectfully submitted,

GEO. H. HOWISON.

Boston, Sept. 11, 1876.

DEPARTMENT OF MODERN LANGUAGES.

REPORT FOR 1875–6.

President Runkle,

DEAR SIR: — Permit me to present herewith the report of the department of Modern Languages for the school year 1875–6.

FRENCH REQUIREMENT FOR ADMISSION.

The following table exhibits the results of the entrance examinations in French for the four years that the same has been one of the requirements for admission to the school, the autumn examination of 1876 being included.

1873	1874	1875	1876	
70	41	71	43	No. of students in First Year.
53	49	53	57	Average mark at Entrance Examination.
15	5	3	0	No. admitted without French.
49	26	51	25	No. admitted without conditions.
81	66	61	65	Average mark.
21	15	20	18	No. admitted with conditions.
10	19	32	33	Average mark.

From this it appears that there has been a gradual improvement in the manner in which the requirement has been fulfilled, as indicated in the following particulars :—

1. The average mark of the whole class has slightly increased.

2. The number admitted without any French has constantly diminished, until the present year, when there were none.

3. The average mark of those admitted under condition has constantly increased.

It is to be mentioned moreover, that there has been twice a small increase in the amount required. The requirement at present is; in grammar, "through regular and irregular verbs," that is the more prominent and essential principles of the same; and in reading, "the first two books of *Charles XII*," that is about sixty pages. As will be seen from the last examination paper for admission published in the annual catalogue, and also from the statements and suggestions regarding the preparation in French also contained there, it is only the prominent and essential facts of the language that are required of the candidate. But it is expected that he will know these facts well and have them at ready command.

Each candidate is also examined in pronunciation, in so far as to pronounce a short passage, and his performance of the same is noted with reference to three or four facts of French pronunciation, and judged accordingly. Deficiency in fluency, general style of pronunciation, and minor matters are not counted against him. But, as the marks show, the performance of candidates on so moderate a test, falls considerably below that on the written paper. A fair understanding of and familiarity with the prominent facts of pronunciation can be obtained without great difficulty, and the matter is one of considerable practical importance in the farther prosecution of the study.

At present, the amount of French which students have on entering, can hardly be said to represent a year's work, and it would seem to be more advisable to insist upon greater thoroughness in what is now required, than to add to the amount of the same.

It may be interesting to notice, that of the fifty-eight candidates, as regular and special students, for the FIRST YEAR at the last examination, forty-four stated that French was a regular study in the school where they prepared, and, thirty-five that Latin also was, while thirty-eight reported that they had studied Latin.

WORK OF THE PAST YEAR.

The number of exercises per week in the department were 31 the first term, and 28 the second. The following view shows what was read and the amount:

FRENCH.

First Year. "Bôcher's Reader," 100 pages. "Les chemins de fer" — Guillemin, 100 pages.

Second Year. Mérimée — "Lettres d' Espagne," 50 pages. Taine — "Notes sur l' Angleterre," 150 pages. This class had French exceptionally the first half of the year, in consequence of the omission of one of their courses in another department.

Fourth Year (first half.) "Bôcher's Reader," 100 pages. About — "Roi des Montaignes," 50 pages.

GERMAN.

Second Year. "Whitney's Reader," 34 pages. Grimm's "Märchen," 67 pages.

Third Year. "Whitney's Reader," 55 pages. "Wind und Wetter" — Lommel, 25 pages. "Eigensinn"—Benedix, 22 pages. "Die Braune Erika" — Jensen, 55 pages.

Fourth Year. (students in Sci. and Lat. and Philosophy.) Portions of Schiller's "Wallenstein," and two easy comedies.

Exercises in composition, written and oral, and on the forms and principles of the languages in question, have accompanied the above work in translation.

During the second half of the year, the students in Science and Literature, and Philosophy, pursued, as indicated in the catalogue, a course in the *Science of language*, using as text book Whitney's "Language and the study of language." During this half also there was an optional class of three students, that commenced Italian.

Certain students of the FIRST YEAR, who were admitted on condition in French, and who were much behind the other members of the class, were formed into a class by themselves, reciting oftener than the rest. This Elementary class numbered seventeen, and was united with the regular FIRST YEAR at the Semi-Annual.

TECHNICAL READING.

As indicated above, popular works of a scientific nature have been used to a considerable extent for reading in both French and German. These seem to interest the students more than works of a purely literary nature, and convey practical information, bearing more or less directly on the special profession of the same. Strictly professional and technical reading would hardly be practicable in a class made up of students pursuing different professional courses, and where the main object is to obtain a knowledge of the language. Exercise in such technical reading wonld be in place in each special department.

Following are the examination papers at the Annual, of the FIRST YEAR in French and THIRD YEAR in German, with the average mark of the whole class on the same.

Respectfully submitted,

CHARLES P. OTIS.

October, 1876.

[EXAMINATION PAPER OF THE FIRST YEAR AT THE ANNUAL.]

Number of students 62. Average mark 64.

I. *Translate.* — Il s'agissait d'ouvrir entre Modane et Bardonèche une galerie souterraine qui, partant de la vallée de l'Arc, allât déboucher en Italie, sur le versant opposé, dans la vallée de la Dora. 12,220 mètres à franchir, voilà pour la longueur du tunnel; une épaisseur de 1800 mètres de roches, voilà pour la profondeur. Vous rendez-vous compte, maintenant, des difficultés de tous genres que rencontre le percement? Avant que les deux têtes du souterrain puissent être reliées par une galerie de 12,000 mètres et qu'un courant d'air s'y établisse, l'air pur manquera mille fois aux ouvriers, dans un milieu vicié tout à la fois par leur respiration, par la combustion des lampes et par celle de la poudre. GUILLEMIN.

1. Indicate the relation to the verb of all nouns and pronouns in "*Vous rendez-vous compte des difficultés que rencontre le percement.*"

2. Point out and explain any instance of the subjunctive you see in the translation above.

3. Account for the ending of the participle in *puissent être reliées* and render in French "*the difficulties which we have met up to this day.*"

4. Explain the forms *s'agissait*, *partant*, *allât*, *puissent*, giving the principal parts of each.

5. Conjugate in full the present subjunctive of *ouvrir*, *allât*, and imperfect subj. of *rencontre* and *puissent*.

Translate. — The engineers fear that the workingmen may suffer from want of air. Unless a current of air is established, the men will not be able to work. Is it true that they are to build an iron bridge over the Hudson.? I think they will build one.

II. *Translate.* — Puisque je vous ai dit un mot du choix de l'eau c'est le moment de parler de celui du coke.

Une seule question, interrompis-je, ne brûlez-vous donc jamais de houille, ni de bois.—

— De bois, cela ne m'est pas arrivé. J'ai ouï dire toutefois qu' à l'étranger, en Amérique, en Allemagne, on chauffe les machines au bois. Quant à la houille, si elle est un peu grasse, elle gêne le tirage, dans tous les cas, elle donne trop de fumée. On la réserve pour la conduite des trains de marchandise. Jadis on nous donnait des cokes de médiocre qualité, aujourd' hui les compagnies s'attachent à nous fournir les meilleurs combustibles: ce n'est pas nous qui nous en plaignons, demandez plutôt à mon chauffeur.

GUILLEMIN.

1. Why the compound of present in "*je vous ai dit*," the preterit in "*interrompis-je*," and the imperfect in "*on nous donnait*," etc.

2. What is the English equivalent of "*on chauffe les locomotives*;" give this sentence another construction without changing the meaning.

3. Give the principal parts of the verb *plaignons*.

4. Explain the form of the demonstrative pronouns *celui* (*du coke*), *c'* (*est le moment*), *cela* (*ne m'est pas arrivé*).

Translate. — We used to heat our house with coal, now we heat it with steam. Rails are being laid rapidly. He complained of the poor quality of the coal that was given him.

III. (*Passage not translated in class*). — Un certain jour d'automne, Mattéo sortit de bonne heure avec sa femme pour aller visiter un de ses troupeaux dans une des clairières du mâquis. (1) Le petit Fortunato, son fils, voulut l'accompagner, mais la clairière était trop loin. D'ailleurs, il fallait bien que quelqu'un restât pour garder la maison; le père refusa donc. On verra s'il n'eut pas lieu de s'en repentir.

Il était absent depuis plusieurs heures, et le petit Fortunato était tranquillement étendu au soleil, regardant les montagnes bleues, quand il fut soudain interrompu dans ses méditations par l'explosion d'une arme à feu. Il se leva et se tourna du côté de la plaine d'où partait ce bruit. D'autres coups de fusil se succédèrent, tirés à intervalles inégaux et toujours de plus en plus rapprochés; enfin, dans le sentier qui menait de la plaine à la maison de Mattéo parut un homme; ——— il venait de recevoir un coup de fusil dans la cuisse. (2)

MÉRIMÉE.

(1) glade; (2) thigh.

1. Explain the forms *restât, fut interrompu, se succédèrent.*

2. What is the force of the preposition *à* in *arme à feu*, of *de* in *coup de fusil* and in *venait de recevoir.*

3. Point out in the translation one or two instances of an infinitive not preceded by any preposition and give the rule for it.

4. Give the compound of present of *aller, verra, se succédèrent.*

5. Conjugate the present indicative of *voulut* and *se repentir*, the future of *parut* and the present subj. of *venait* and *recevoir.*

Translate. — Setting out in the morning he went to the town to buy gunpowder. He has just left, but he will return after having done his work. On rising he saw a man coming.

IV. *Translate 8 of the following sentences.* — 1. While running, one of the wheels of the carriage was broken. 2. Although this book does not describe all the methods, it gives a good idea of them. 3. I am very glad that you take a trade. 4. We believe that God made the world. 5. It is said that he will be put to death. 6. We wish to know what these workmen are doing. 7. Here the track will have to pass over a river. 8. What direction is to be chosen for that railroad? 9. Could you reach the depot in time? 10. No! when I reached it the train had left. 11. The man whose vanity dies is dead. 12. I shall remember the Sundays that I spent with them.

First Year. May, 1876.

[EXAMINATION PAPER OF THE THIRD YEAR AT THE ANNUAL.]

Number of students. 43. Average mark, 61.

I. Und ſo wuchs ſteigend die Bewegung nach allen Seiten, und neben Bußen, Gebeten, Klagegeſängen und Faſten traf man die allgemeinſten, die umfaſſendſten Vorbereitungen zu neuen Zügen. Bald fragte man nicht mehr, wer mitgehe, ſondern wer zurückbleibe? Und die Zurückbleibenden wurden als feige und weibiſch verlacht und verſpottet, während Mütter ihre Söhne, Weiber ihre Männer befeuerten und klagten, daß die Schwäche ihres Geſchlechtes ſie von Heldenthaten zurückhalte. Kaum ſchien es der Reizmittel zu bedürfen welche die Kirche aus der Fülle ihrer Macht den Pilgern bewilligte: Ablaß, Befreiung von Zinszahlungen, Schutz für die Güter der Abweſenden, u. a. m. Raumer.

II. Außerdem brach ein ſolcher Mangel ein, daß man ſogar Pferdefleiſch aß und Pferdeblut trank. Aber ungeachtet dieſer ſchrecklichen Lage hielt Friedrich ſtrenge Mannszucht und beſtrafte, ſelbſt nach dem Zeugniſſe ſeiner Feinde, jeden Frevel und jede Unzucht an den Geringeren, jeden Mißbrauch der anvertrauten Gewalt an den Vornehmen. So ſtrenge Mittel kamen indeß nur gegen wenige in Anwendung; im allgemeinen zeigten die Pilger in Noth und Gefahr eine faſt unglaubliche Geduld und Ausdauer. Einzelne' welche verzweifelnd zu den Türken übergingen und dem Chriſtenthume entſagten, galten für keinen wahren Verluſt. Raumer

III. M. Geſchwind! Geſchwind!
Rette dein armes Kind!
Fort! immer den Weg
Am Bach hinauf,
Ueber den Steg,
In den Wald hinein,
Links, wo die Planke ſteht,
Faß es nur gleich!
Es will ſich heben,
Es zappelt noch!
Rette! Rette!
F. Beſinne dich doch!
Nur einen Schritt, ſo biſt du frei!
M. Wären wir nur den Berg vorbei!
Da ſitzt meine Mutter auf einem Stein,
Es faßt mich kalt beim Schopfe! Göthe.

IV. 1. Case and construction of Reizmittel (I); Chriſtenthume (II); Weg (III); of mir, in „folge mir;" of Sinnen, in „umſonſt, daß trocknes Sinnen hier die heil'gen Zeichen dir erklärt;" of Mondenſchein, den and Mitternacht, in „O ſähſt du, voller Mondenſchein, zum letztenmal auf meine Pein, den ich ſo manche Mitternacht an dieſem Pult herangewacht!"

2. Construction of ſteigend and feige (I). Is Feinde (II) Subjective or Objective Gen., and why? Geſchwind and immer (III) modify what? To what does es (nur) (III) refer? Decline ihre Söhne (I) and keinen wahren Verluſt (II).

3. Principal parts of ſteigend, fragte (I); galten (II); ßt (III). Inflect Pres. Indic., Active and Passive, of aß (II).

4. Analyze Bewegung, Klagegeſängen, Vorbereitungen, bewilligte (I); unausbleiblich, Wiedervergeltungsrecht, Unentſchloſſenheit, Nothwendigkeit, Waſſerſtoffgas, Wiederbelebung

5. What is meant by Primitive words? In accordance with what three principles are derived words formed? State four ways in which compound adjectives are formed.

6. Explain the subjunctives mitgehe, zurückhalte (I); wären (III); möchte in „es möchte kein Hund ſo länger leben;" wären, in „er behandelte die deutſchen Geſandten ungebührlich, als wären ſie ſeine Unterthanen."

7. Give the English *historically* connected with Theil, Würde; the endings -heit, -niß, -ſchaft, -thum; fangen, Dach, bleiben, bringen, treten, wachſen, fahren, heben, ſchlagen.

8. *a.* State what you known about the Hohenstaufen. Which crusade was this, and when did it take place? *b.* From what two points of view can we look at the Faust drama? *c.* State what is said about the Monsoons and Etesian winds.

9. Translate: 1. He told me day before yesterday that he always rose at half past five, was in very good spirits, and worked the whole forenoon.

2. Many houses in our city have been destroyed by the storm, two of which belonged to my uncle. 3. If the farmer had worked over his garden early in the Spring, he would have had much finer vegetables.

V. Hastily she tore[1] herself away from Raymond, and flew out of the door. The gigantic dog sprang after her with a merry[2] bark. At the same moment all weariness returned[3] into the eyes of the Professor as if *poured out*[4] in a stream. His head fell sleepily upon the hay, and in a few seconds fast sleep had overpowered[5] him.

Erica sat outside under the firs,[6] and sang a soft[7] melancholy song, the commencement of which he heard.[8] But farther and farther did it sound,[9] and strange dream pictures took captive[10] his senses. In his study every thing began to grow animate,[11] and rustled[12] about the arm chair on which he sat.

[1]reißen. [2]heiter. [3]zurückkehren. [4]ausschütten. [5]übermannen. [6]die Föhren. [7]leise. [8]vernehmen. [9]klingen. [10]gefangen. [11]lebendig. [12]rascheln.

VI. (Passage not read in class.) Die Frage, ob das Wasserstoffgas athembar sei oder nicht, hatte ursprünglich zwei ganz entgegengesetzte Antworten erhalten. Priestley und seine Partei behaupteten, diese Luft sei irrespirabel, während Scheele und seine Anhänger gerade das Gegentheil versicherten. Das veranlaßte Fontana, den Versuch an sich selbst zu wagen. Er vermischte Wasserstoffgaß mit atmosphärischer Luft zu gleichen Theilen und fand kaum eine Spur von Unbequemlichkeit bei dem Einathmen dieser Luftmischung, im Gegentheil wollte es ihm scheinen, als wenn er dadurch eine gewisse Leichtigkeit im ganzen Körper verspürte, die ihm wohlthat. Dies gelang auch noch, wenn er abwechselnd reines Wasserstoffgas und atmosphärische Luft einathmete. Sobald er aber versuchte, das Wasserstoffgas ganz unvermischt und ohne Wechsel einzuathmen, so stürzte er bewußtlos zu Boden und wäre sicher ein Opfer des Todes gewesen, wenn seine Umgebung nicht rasch zu Hülfe gesprungen wäre und die passendsten Mittel zur Wiederbelebung angewandt hätte. Birnbaum.

[1] Hydrogen gas.

LOWELL FREE COURSES FOR 1875–76.

Department of Physics.

To President Runkle.

MY DEAR SIR:—In response to your request, I would state the following facts regarding the lectures given by me in the Lowell Free Courses for 1875–6.

These lectures were designed to furnish a somewhat extended discussion of the topic of light in its various relations to color and to vision in general, the subject being considered both from a physical and physiological point of view. Much of the matter concerning the physiological side of the phenomena under consideration was not, at that time, accessible to the general reader, no reliable English works upon the subject having been published, and only a very limited portion of it had been treated in any public course of lectures in the country.

The attendance upon the lectures (eighteen in number) varied from a minimum number of fifty to a maximum of one hundred and ten, the average number being about sixty.

The following is a list of the principal topics discussed in each lecture.

I. Light considered objectively. Propagation of Light. Undulatory Theory, and recent suggestions regarding it.

II. Reflection, Refraction, Dispersion.

III. Polarization.

IV. Anatomy and Physiology of Human Eye.

V. Sensation of Light. Müller's Principle of Specific Action of Senses. Modality of Sensations.

VI. Constitution of Luminous Spectrum. Theories of Color of Newton, Brewster and Young. Experiments of Maxwell and Helmholtz.

VII. Color Blindness. Field's Chromatic Equivalents.

VIII. Physical Causes of Color. Colors of Luminous Bodies. Colors of Non-Luminous Bodies. Production of Color by Absorption and Internal Reflection.

IX. Production of Color by Metallic Reflection and Dispersion. Turbid Media. Goethe's Theory of Color. Fluorescence and Phosphorescence.

X. Colors Produced by Interference of Light. Phenomena of Thin Plates and Diffraction.

XI. Chromatic Phenomena of Polarized Light.

XII. Compounding of Colors. Modes of Studying Complementary Colors.

XIII. Geometrical Systems of representing color-variations in Hue, Tint and Shade.

XIV. Measurement of Intensity by Photometers. Effect of variations of Intensity on Saturation of Colors. Irradiation.

XV. Persistence of Sensation. Laws of Duration of Impression. Stroboscope and applications.

XVI. Modifications of Excitability. Positive and Negative After-Images. Rate of Excitation of different color-sensations.

XVII. Successive Contrast, its Phenomena and Laws. Simultaneous Contrast. Contrast of Colors of same hue.

XVIII. Simultaneous Contrast concluded. Contrast of Colors of different hues. Chevreul's Law. General Law of Simultaneous Contrast and Explanation of Phenomena.

An examination of the preceding summary of topics will show that Lectures I. — III., inclusive, were devoted to a brief description of the principal facts of Physical Optics, which was a necessary introduction to the matter afterwards discussed.

In this connection I wish to call your attention to an experi-

ment which I was enabled to carry into effect through the generosity of a member of the Corporation of the Institute. In previous similar courses there had seemed to be a great need of some concise statement of the principles of the subject under consideration, to which the audience might be referred. It appeared that a very brief series of printed notes, comprising one or at most two printed pages for each lecture, and containing a brief summary of the results finally attained, without attempting any description of apparatus or experiments, would greatly enhance the value of the lectures to those in attendance. The result of the trial more than justified the expectation, and from the general desire on the part of the audience to keep a complete set of the notes, together with the expressions of many persons as to their service, I am very certain that the value of such notes can hardly be over-estimated. It would be a very considerable addition to our work for the public if this method could be generally adopted in our Lowell Courses.

All of which is respectfully submitted,

CHAS. R. CROSS.

Kant's Critique of Pure Reason. Eighteen lectures for beginners.

President J. D. Runkle: —

The attendance on the first four of these lectures, given Mondays and Wednesdays at 7½ P. M., commencing Nov. 18, which were of an introductory and general character, was about fifty, nearly half of whom were women. The remainder of the course, devoted to instruction upon the details of Kant's text, was of necessity less interesting to many, and the attendance was at once reduced to some twenty-five, who continued however, to the end. Four of the attendants afterwards joined the class in the Department of Philosophy, as special students of the course on Kant there.

GEO. H. HOWISON.

Physiology and the Laws of Health. Eighteen lectures.

At the Lowell Lectures on Physiology and the Laws of Health, at the Institute, in the winter of 1875-76, there was an average attendance of fifty, principally female teachers. The lectures were illustrated by the skeleton, separate bones, models, life-size engravings, diagrams, and tables on the blackboard.

As the main object of these lectures was to teach the few and simple rules of health, so easy to violate, so difficult to return to without great inconvenience and suffering, only so much technical anatomical detail was introduced as was necessary for understanding the laws of physiology and hygiene. Under the bones were dwelt upon the deformities of civilization, distortions of the spine, chest, hips, and limbs, frequently produced by parents and nurses in the child, confirmed by improper attitudes in school, and uncorrected by teachers, from ignorance or carelessness. Under muscles, the natural correctors of the above deformities, the evils of sedentary habits and the dangers of excessive muscular exertion, the latter of which is, in the present mania for athletic sports, productive of great physical injury, were considered at length.

The phenomena of nutrition, beginning with digestion, from the taking in of food to its conversion into blood, were then examined; — including the composition and uses of the various kinds of food, their nutritive qualities, digestibility, and adaptibility to age, season, climate, and occupation, — the chemical, mechanical, and vital processes carried on by the vessels, glands, muscles, and secretions of the different parts of the alimentary canal — absorption of nutritive materials and their conveyance to the heart — their purification in the liver and lungs — the circulation, pulmonary, systemic, and portal — respiration and animal heat — and the final purifications effected through the lymphatic and other glands, the kidneys, and the skin.

The dangers attendant upon abuse of these various organs, their most common diseases, and nature of the means of cure,

were then explained from the standpoint of elementary physiology, not of medical science.

The course ended by a description of the brain, nerves, and special senses, showing how this complicated body is regulated, and may be preserved from danger, if attention be paid to their timely warnings. SAMUEL KNEELAND.

General Chemistry. Twenty-four laboratory exercises.
Qualitative Analysis. Twenty-four laboratory exercises.

The usual laboratory facilities have been afforded this winter to persons of both sexes who desired to study either General Chemistry or Qualitative Analysis, the text books and methods of instruction being the same as employed in previous years, and as described in the last Annual Report.

W. R. NICHOLS.

Heat and its Applications. Eighteen lectures.

President Runkle,

DEAR SIR: — In the Lowell course of eighteen lectures on Heat and its Applications, the principal topics considered were as follows: —

I. Older and newer theories respecting the nature of heat. How heat makes itself known. Correlation of forces. Distinction between accepted theories and positive knowledge.

II. Sources of heat. Resisted motion. Rumford's, Joules and Hirsch's experiments on friction and the mechanical equivalent of heat.

III. Conduction of heat by solids, liquids and gases. Non-conductors and their uses. Clothing. Spheroidal state of liquids. Convection. What are suitable carriers of heat.

IV. Radiation. Good and bad radiators. Resistance to radiation. Transcalence. Melloni's experiments on transmission. Tyndall's experiments on the intercepting power of gases and vapors.

V. Absorption, destruction, or conversion of heat. Expansion of bodies. Differential expansion. Thermometers of various kinds.

VI. Pyrometers. Thermomultiplier. Specific heat. Expansion by mechanical means as compared with expansion by heat. Determination of mechanical equivalent by the expansion of air.

VII. Absolute zero. Thermometric scales. Latent heat. Calorimeters. Freezing mixtures.

VIII. Boiling points. Superheated liquids. Nature of vapors and gases.

IX. Solution of gases in water. Distillation. Fractional distillation and fractional condensation. Analytic condensation.

X. Tension of vapors. Superheated steam. Occlusion of gases by metals, charcoal, and coal. Combination of bodies by volume.

XI. Production of heat by chemical action. Fermentation. Respiration. Combustion in air. Combustion in oxygen.

XII. Fuels. Sulphur and sulphides. Combustibles produced by plant life in different geological epochs.

XIII. Progressive changes of vegetables to form peat, brown coal, bituminous coal, anthracite. The manufacture of charcoal.

XIV. Artificial fuels. Gaseous fuels. Siemen's regenerative furnace.

XV. Fireplaces. Altars. Forges. Kilns. Reverberatory furnaces.

XVI. Heating dwellings. Hot water circulation. Steam heating, direct and indirect. Hot air furnaces. Open grates. Stoves.

XVII. Heat as a motive power, or the conversion of heat into motion. Hot air engine. Wind power. Steam power. Water power. Gunpowder engine. Carbonic acid engine.

XVIII. Cosmic heat. Utilizing the sun's heat. Conversion of heat into light. Origin of all force.

Experimental illustrations were introduced as far as possible, but in giving two evening lectures a week in addition to my ordinary daily duties, I could not make as much preparation as was desirable in the way of demonstrative experiments. Whenever lectures require such aids for elucidation I believe it would

be better both for the audience and the lecturer to let the course extend over a greater length of time and have but one exercise each week.

Respectfully yours,
JOHN M. ORDWAY.

Elementary German. Eighteen lessons.

President Runkle,

DEAR SIR: The Lowell course of eighteen lessons in "Elementary German" assigned to me was commenced Monday, Nov. 22, and continued Monday and Wednesday evenings until finished Jan. 19. The average attendance was forty-five, the number at the beginning being a little larger, that at the end a little smaller than this, the number present varying but little from evening to evening. About a third, I should think, of those attending were men, mostly young men.

The object of the course was to present in a concise and clear manner the *more essential facts of the German language*, with *writing and oral exercises* for the sake of practice. It was found necessary to arrange the course and treat the subject quite differently from what would have been practicable with a class of students, at the Institute for instance, of about equal age and attainments and with time at their disposal for preparation and outside work. For, the class of persons who presented themselves for the knowledge in question differed widely from such students in all of these respects. Some were advanced in life, some were young, some had studied German before and were desirous of reviewing the subject, others were beginners, some had time for study outside of the lecture hour others had not, some had had previous training in language others none. It was desirable therefore to pursue a course requiring as little previous knowledge and training as possible, and little or no outside work, while at the same time the instruction was to be of a systematic and thorough character. The especial features

of the method pursued for accomplishing this object were the use of the *blackboard as text-book*, with regular exercises in *German composition and reading.*

Before the hour for the lecture, such essential grammatical *forms and rules* as were embraced by the subject to be studied during the evening were written on the blackboard, in a concise form and one best adapted to catch the eye and impress itself upon the memory. These the class were requested to write down in note books, as also such things in the exposition given of the subject as might seem necessary. After the exposition of the subject for the evening, followed the writing of sentences involving particularly the principles and facts just presented. Such sentences were written by all in blank-books provided for the purpose. At the end of the hour the majority handed in their books, which were examined and returned at the beginning of the next lecture with the errors indicated.

The only trouble in such a mode of working is the difficulty persons, who have not had practice, find in *taking notes* that are reliable in point of accuracy and completeness. This might, however, be obviated by having the class provide themselves with a short manual containing the essential facts of German grammar, to which they could refer for the forms and so much as might be necessary of what was presented in the exposition. In spite, however, of this drawback the class worked with reasonably satisfactory results, as shown by the exercise books and the continued interest in the subject.

Following is given an outline of the lectures, showing the topics treated at each one. It will be seen that, with the exception of the verb, each topic was taken up and finished by itself. Eight of the eighteen lectures were devoted to the *verb*, as being of much more importance in German than the other parts of speech. In the case of the verb alone the treatment was interrupted, the more essential part being presented first, and the subject afterwards resumed, partly for the sake of introducing earlier other topics demanding attention, and partly

in order to give variety to the work. The *order* in which the subjects were presented was different, it will be seen, from that usually adopted in grammars, but one which seemed most natural and most favorable for unfolding the facts of the language, as also for showing in the proper light the *more important* as distinguished from the *less important.*

I. *Pronunciation.*
II. *Articles. Possessive Pronouns.*
III. *Verb*: simple tenses of a verb of the *New conjugation.* (*Demonstrative and Relative Pronouns.*)
IV. *Verb*: simple tenses of a verb of the *Old conjugation.* (*Use of the tenses.*)
V. *Verb*: compound tenses of the new and old conjugations. (*Use of the tenses.*)
VI. *Verb*: *separable verbs.* (*sein* for *haben* as tense auxiliary).
VII. *Order of the German sentence.* (*Inseparable verbs.*)
VIII. *Personal Pronouns.*
IX. *Adjective*: I and II declensions.
X. *Adjective*: "mixed" declension.
XI. *Adjective*: comparison.
XII. *Adjective*: numerals.
XIII. *Noun*: I declension.
XIV. *Noun*: II declension.
XV. *Verb*: passive voice.
XVI. *Verb*: passive voice.
XVII. *Verb*: reflexives.
XVIII. *Verb*: impersonals.

In order to present to the class at the outset, and keep constantly before them the *actual language*, a small selection of very short selections in poetry and prose, the easiest things to be found, were printed and distributed. These served at each meeting as exercises for pronunciation and translation.

Respectfully submitted,

CHARLES P. OTIS.

The Elements of Perspective. Eighteen lectures.

This course consisted of nine lectures and nine lessons, the lessons being taken up with explanations and the examination and correction of drawings made by members of the class, which consisted of about forty persons, men and women. A printed syllabus containing the propositions to be explained was furnished at each exercise.

The instruction differed from that generally given and from that contained in the text books in several particulars, much greater prominence being given to the phenomena of parallel planes than is usual, and use being made of the laws established to determine the perspective of shadows, a subject that has hitherto received but little attention.

In the course of this discussion it was shown that the paramount importance commonly assigned to the horizontal plane and to the horizon line is unnecessary, and that the practice of referring everything to that plane is productive of needless inconvenience. It was shown that every plane has, so to speak, its own horizon, in which all the lines that lie in the plane have their vanishing points.

The well-known method of points of distance, also, which is generally treated as an auxiliary method of but limited serviceability, was shown to be of universal application, and to suffice for the solution of all problems. The developement of this method was shown to lead to the construction of a perspective plan, taking the place of the orthographic plan by the aid of which perspective drawings are commonly made.

The first part of the course was given to the study of the phenomena with the representation of which the art of drawing in perspective is concerned, and to what may be called a *qualitative* discussion of the subject, as distinguished from the *quantitative* discussion which followed, in which the representation in perspective of exact dimensions was explained. This first part of the course was addressed especially to artists and amateurs, to assist them in sketching.

This discussion involved the subject of the so-called errors of perspective and of the discrepancies that are always found to exist between drawings made from nature and those made by the rules of plane perspective. It was shown that drawings made from nature are in fact made in accordance with the rules not of plane but of cylindrical perspective, — what is sometimes called curvilinear or panoramic perspective, — and the principles and methods of this system were explained and shown to coincide in their result with drawings made directly from objects. The relative advantage of the two systems was discussed, the cases pointed out in which each was to be preferred, and the devices and accommodations explained by which the disadvantages of each may be palliated in practice.

The course closed with brief review of other systems, especially of the system of coördinates and of the *Système Adhemar*, to which was added an investigation into the perspective of reflections.

Throughout the course it was maintained that a problem in perspective cannot be considered to be entirely solved unless the solution gives the vanishing point of every line that is drawn, and the vanishing trace, or horizon, of every plane, a solution which the commonly received methods fail to supply.

WILLIAM R. WARE.

ABSTRACTS OF THESES PRESENTED BY GRADUATES OF 1875-76.

DEPARTMENT OF CIVIL ENGINEERING.

Providence Water Works. Abstract by the author, T. Aspinwall, Jr., May, 1876.

The water supply of the city of Providence is taken from the Pawtuxet river. The main pumping station is situated close to the river, on low land, and is called, from the Indian name of the place, Pettaconset.

The machinery for pumping consists at present of two pumping engines, a Cornish and a Worthington Duplex. The latter is only intended for temporary use here. It has a capacity of 5,000,000 gallons, pumped 180 feet high in twenty-four hours. The Cornish engine, however, is permanent and has a capacity of 9,000,000 gallons. The engine house is designed to contain four Cornish engines of like-dimensions. The Cornish engine pumps into a standpipe 182 feet high, connecting with Sockanosset reservoir. The latter has a capacity of 51,156,544 gallons. Its construction, together with that of its gate chambers was described.

The main to the city was then described, particularly at the crossing of Pochasset brook by a triangular truss, and at the Pawtucket river, which the main crosses on iron screw piles.

The reasons for the construction of Hope reservoir were then

stated, the construction of the gate chambers described, and their action explained.

Hope pumping station was next taken up. The engines here are two in number, each being of the capacity of 5,000,000 gallons in twenty-four hours. One is of a pattern designed and built by Geo. H. Corliss, Esq., and the other of a form designed by A. F. Nagle, M. E., of the Providence Water Works and built by the Providence Steam Engine Company.

The paper concluded with a short account of the pipes used in the mains, giving the formula by which the thickness was calculated and a table containing the results of those calculations for every diameter.

Merrimac River Bridge at Nashua, N. H. Abstract by the author, T. W. Baldwin.

I have commenced this thesis with a full description of the abutments, piers and superstructure of the bridge. Next I have calculated analytically and graphically the stresses arising from a uniform live load of 2500 lbs. per foot. Then follows a calculation of the web stresses when the bridge is partially loaded. Having found all the maximum stresses I have calculated the necessary dimensions of the girders and compared them with the actual dimensions. Next I have made calculations to see whether the factor of safety necessary to be used, in order that the working strength of the posts and braces shall be sufficient to withstand the stresses brought to bear upon them, is of proper size. I have finished by inserting a "Bill of Timber and Iron" together with the weight of each piece, in order to compare the actual weight with the weight assumed in the calculations.

I have made two drawings, one of the plan, side and end elevations of one span of the bridge, and one giving on a larger scale some details of the bridge and masonry.

West Chester Park Bridge over B. & P. R. R. in Boston, Mass. Abstract by the author, J. B. F. Breed.

This is a wrought-iron through highway bridge with three roadways and two sidewalks.

It consists of six girders, four of which are lattice girders and two are plate girders.

I have first given a detailed description of the bridge and then proceeded to calculate the maximum stresses in the diagonals and chords of lattice girders and in the flanges and webs of plate girders. This is followed by the determination of the net area of cross-section and the number of rivets required in the different pieces.

The stresses on the floor-beams and stringers are next considered and the requisite size and form of these fixed. Finally I have computed the total weight of the bridge and thus determined the true dead load.

The thesis is accompanied by plates of drawings representing elevations, sections, plan and details of the bridge.

The Buffalo Water Supply. Abstract by the author, H. T. Buttolph.

The city, first supplied by a private company in 1852, bought the works in 1868. There was much need of improvement, in order to fill the wants of the rapidly growing city, and it was thought they could be more fully carried out under the city government.

The improvements to be made, were to furnish the city with a *plentiful supply of pure water*; to supply a district higher than the level of the existing reservoir; and to lay the pipes low enough to avoid the effects of frost, the freezing of the pipes as then laid being a great inconvenience to the people during the winter season.

The first improvement was made by excavating a tunnel under Erie Canal, Black Rock Harbor and under Niagara River to a point 1020 feet from the pumping station on shore; where was erected an inlet pier with the requisite gates to control the supply.

The pier is 30 feet high, 114,662 feet long, 18 feet wide at the base, and the platform is 15.5 feet wide, battering planes intersecting it, which narrow it at the ends. This platform

from end to end is 37 feet in length. The shaft in the pier is 6 feet in diameter and extends down to the tunnel, nearly 60 feet. The tunnel is at an average depth of 17 feet below the bed of the river, and has a section 8 feet square. The tunnel was five years in building; many obstacles being met, the principal of which were the great leaks of sulphur water. These leaks were encountered at two separate times; the first about 500 feet from Black Rock Harbor, where the water came up through the bedrock, which is a very soft limestone, at the rate of 3500 gallons per minute.

By putting in a wrought iron shield, 6 feet in diameter and 24 feet long, the flow of water was nearly stopped; and the work was carried about 89 feet farther where the second and more disastrous leak was met with. Here the water came in at the rate of 4500 gallons per minute, and the leak delayed the progress of the work nearly fifteen months. During this time the contract of the work passed into other hands.

Ten Blake pumps were put into the bottom of the shaft on shore. Five were put into operation with a capacity greater than the flow of water and by this means the water was kept out of the tunnel, so that the work was carried on. Above the strata through which the water flowed there were harder ones, and after overcoming the second leak the tunnel was raised three feet, top and bottom, in order to carry it through the harder rock.

The formal announcement of the completion of the work was made November 6th, 1875; the work was begun on the 12th of May 1870.

In 1870 the Holley System was introduced to supply the higher district. And in the spring of 1874 over three miles of pipe was taken up and relaid, the bottom of the new trenches for the pipe being six feet below the grade of the streets.

The pumping is at present done by a Compound engine, Shepard engine, and Worthington duplex engine; each of the capacity of 10,000,000 gallons in twenty-four hours. The last named engine does the principal part of the pumping, the Com-

pound doing the least and in the place of which there is being built a Worthington duplex engine of 15,000,000 gallons capacity. The Holley pump takes its supply from the main, through which the engines at the pumping station force the water to the reservoir.

During the winter of 1872–3 the city was twice left without a supply of water, once for nearly forty-eight hours. A protracted east wind forced the water out of the harbor and left the waters in the pumping wells below the reach of the pumps. When the wind changed the water rose again. This trouble can not come up, under the present condition of the works.

The Bridge over Front St., in the Viaduct at Worcester, Mass.
Abstract by the author, Fred'k K. Copeland.

After a short description of the bridge and the conditions under which it was built, the dead load was approximately calculated.

The stresses in the web members were calculated for both live and dead load and the results combined. Having obtained the stresses in the trusses, the area of the cross-section required was compared with that actually provided, which showed at once any deficiency in strength of any part. The rivets and pins were calculated both for shear and bearing; the number of rivets used, in all cases, was largely in excess of the number required.

The posts were calculated by "Gordon's formula"; their area being given, their ultimate strength, and from this the factor of safety used was calculated, the smallest value of the latter being over four. The floor beams are plate girders hung from the trusses by suspending straps. These beams were very heavy as the bridge carries three tracks, and it was not possible to have more than two trusses.

The amount of iron used was found to be sufficient in all but a few parts and in these the deficit was not large. The weight

of iron was calculated and proved the dead load to be less than the dead load first assumed.

The Broadway Draw Bridge, Boston, Mass. Abstract by the author, John R. Freeman.

The first part of this thesis is mainly descriptive, the general form of the pier and superstructure and the form and dimensions of the more important members being explained with reference to the accompanying drawings, and the manner of building the foundation for the centre pier and of depositing the concrete in the depth of water there existing being briefly described. Some of the more important requirements of the specifications as to character of work and quality of materials and the results of tests made to determine the strength of the wrought iron used, are also given.

The maximum load assumed in the specifications is then discussed and next the conditions of loading producing maximum stress in a continuous girder of two spans are investigated. Then starting with the "Theorem of the Three Moments" as given by Weyranch, a formula for the end reaction for this case is derived.

The method used for the determination of the stresses in the different members is that known as "Ritter's Method of Sections". The maximum intensity of stress in each member is then found, and compared with the limit fixed by the specifications.

The remainder of the thesis is taken up by a calculation of the stresses in floor beams, etc.

Accompanying the thesis are three sheets of drawings, showing the whole structure in plan and elevation and the more important parts in detail.

The Albany Street Bridge in Boston. Abstract by the author, F. W. Hodgdon.

The thesis begins by giving a general description of the bridge which is to replace the old iron lattice bridge on Albany Street.

It is to have four trusses 10 feet high and of spans varying from 102 feet to 83.7 feet. They are double Warren girders and the floor beams rest directly on the lower chords. The trusses are held in position by angle bar stays. The roadway is 32.5 feet wide, and each sidewalk is 8′ 9″ wide, making a total width of 50 feet. It is calculated for a load on the roadway of 80 lbs. per square foot live load, and 90 lbs. per square foot dead load, on the sidewalk 100 lbs. per square foot live load, 50 lbs. per square foot dead load.

Then it takes up the calculations, explains the method, and finds the stresses in all the parts.

Using 9000 lbs. per square inch for compression and 8000 lbs. per square inch for tension, it finds the sectional area required for each piece, and compares it with the actual area used, and gives the sizes and shapes of all the iron used in making up each cross section. Everything is reduced to tabular form where possible.

Finally it takes up the subject of riveting, explains the principles and shows its application in the case of this bridge.

The drawings which accompany it show, I. Elevations of each of the four trusses; II. A cross section of the bridge, a skeleton plan and the principal details.

Iron Bridge over the Merrimac River, at Tyngsboro, Mass.
Abstract by the author, A. L. Mills.

In this thesis, I have first given a short description of the bridge and its foundations. I have then given a statement of the loads for which this bridge was calculated, which I obtained from the Engineer, Mr. C. H. Parker.

I then calculated the greatest stresses that could occur on the members from different positions of the live load, giving an explanation of the method used in the calculations. I have found the actual stress in pounds per square inch of section and compared it with the breaking stress per square inch, showing the factor of safety that is in actual operation in the different parts of the bridge. In all cases of compression members I

have used Mr. Gordon's formula for the breaking stress in pounds per square inch. For the tension members I have taken the tenacity of wrought iron rods between 60,000 and 70,000 lbs. per square inch, as given by Rankine. For wrought iron plates I have used, on the same authority, between 50,000 and 60,000 lbs. per square inch as the breaking stress.

I have treated the floor beam, which is a "Pratt" truss of six panels, in the same way that I have treated the main truss.

I have found the stress per square inch on the wooden stringer which lies between the floor beams, and have found it amply strong enough to sustain the load it was intended to bear. Lastly I have calculated the weight of the iron work and planking in the bridge, showing that the dead load was estimated but a trifle too large.

Design for a double track Wrought Iron Post Truss. Four Girders. Abstract by the author, Henry Raeder.

In the introduction of my work I have given a general description of the form of a Post Truss, followed by the conditions under which I designed this special case of that kind of truss.

I then explained the method of calculation I employed, which fundamentally consists in dividing one of the four trusses into two primary trusses and afterwards combining the results of the calculations for the two girders.

The chord stresses I found by Ritter's method of sections, and the maximum web stresses from the corresponding shearing forces, when the girder is most disadvantageously loaded for the section in question. I checked the chord stresses by finding them a second time from the horizontal components of the web-stresses under a uniform live and dead load.

Having found the maximum stresses, I designed the pieces which are to sustain them, using for limit of stress in a tie 50,000 lbs. per square inch and employing Gordon's formula $\left[p = 40{,}000 \div \left(1+\frac{e^2}{\frac{(10{,}000)}{40{,}000}\, r^2}\right)\right.$ to find the limit of stress in

the struts. I employed five for the factor of safety. In the remainder of my work I discussed the details of the structure, and finally calculated the entire weight of one girder, and comparing this *calculated* weight with the dead load *assumed* in the calculations, I found it was smaller.

West Boston Draw. Abstract by the author, C. L. Rich.

This pivot bridge consists of two equal Pratt girders of wood and iron, span of 68.5 feet each; width, including sidewalks, 50 feet, and twelve panels in each span. It is continuous over the three level supports, with a uniform cross-section. Two plate iron girders at the centre carry the weight of the bridge to the pivot. A live load in addition would bring the ends of these girders to bear upon the wheels of the turn-table, so that the centre support always acts through the iron girders at the middle. The ends of the bridge when open are supported by hog chains, passing over Samson posts erected over the centre. These rods, by a pin joint in the upper chord, continue to the lower chord, at the same points as the end support.

The dead load is taken as 45 lbs. per square foot; the live load, 80 lbs. The hog chains and the girders of the turntable are calculated for the open condition. The working strength of wrought iron in tension is 10,000 lbs. per square inch; in compression, 8,000 lbs.; in shearing action, 8,000 lbs.; in bearing on rivets, 10,000 lbs. per square inch. The flanges are assumed to resist the bending; the web, the shearing forces. The girders are of uniform strength. In discussing the trusses, the factor of safety of each part has been determined, which shows the relative strength of the parts. This factor may be smaller here, than in case the maximum load is often obtained.

As a check on the chord stresses, a diagram of the moments was drawn, by representing the positive moments by parabolas whose middle ordinates are $\frac{1}{8}$ Wl, where W is the total uniform load on either span, l, the length of span; and the negative moments by triangles, whose altitudes in a total uniform load,

are $\frac{1}{8}$ Wl; when the live load covers only one span, the altitude is $\frac{(W + W^1)l}{16}$, where W and W^1 are the loads uniformly distributed over each span. The ordinates between parabola and triangle in terms of the moments, divided by height of truss, give chord stresses.

In calculating the stresses, the dead and live loads are taken separately. The first thing is to find the reactions, then shearing forces, chord stresses, or the diagonal stresses.

In the bending action, the loads are considered uniform. Moments tending to produce compression in the upper chord, are called positive; those tending to produce tension, negative. The supporting forces or reactions at the left, right and centre are called R_A, R_B and R_C respectively. R_C and therefore the negative moment at centre are maximum under a full load. $R_A = R_B = \frac{3}{8}W$. $R_C = \frac{5}{8}W$. A half panel load must be deducted from these reactions for shearing forces in the end panels. R_A and therefore the positive moment in the left span, are maximum, and the negative moment extends farthest from the centre, when the left span only contains the live load. Then $R_A = \frac{1}{16}W$, $R_B = \frac{1}{16}W$, $R_C = \frac{10}{16}W$, W being the uniform live load in the left span, while the reactions resulting from the dead load are those in the preceding case.

Shearing forces, which act upward at the left of any section are called positive; downward, negative. The shearing action of the dead load still remains the same. The live load is treated as concentrated at the 11 apices of the lower chord, and the reaction caused by each is separately calculated by three formulas.

$$R_A = \frac{P}{4}[4 - k(5 - k^2)], \quad R_B = -\frac{P}{4} \cdot k(1 - k^2),$$

$$R_C = \frac{P}{2} \cdot k(3 - k^2).$$

where P is an apex load, and k, the ratio between the distance from left support to the load, in the left span, and the whole span.

By supposing the apex loads attached as we wish, and taking

the sum of the reactions of each, as calculated in the 11 cases, we can get any desired condition. The maximum positive shearing force in any bay of the left span occurs, when the live load extends from the centre support bay; the maximum negative shearing force, when the right span is fully loaded and the live load extends from the left support to that bay.

There are trussed floor beams 12 feet apart carrying two longitudinal beams, which support two intermediate floor beams, extending under the sidewalks. The greatest stress in the sidewalk beams occurs under a heavy wagon load; as 20 tons. The trussed beams carry the greatest load, when under the uniform full load.

A prominent advantage of this bridge is its complete rotation.

The Eastern Avenue Swing Bridge in Boston. Abstract by the author, Henry M. Waitt.

This thesis opens with a short statement of the dimensions of the truss, and the extent of loading. Next in turn comes the calculation of stresses. The bridge was considered as continuous over "Four Level Supports". The dead load was considered to produce the same effect on the truss when shut, as when open. The live load in every case, as acting continuously over the four supports. The four reactions, for each individual panel load, were calculated by the formula given in "Dubois' Graphical Statics", pp. 184–5, Art. 122. Having thus obtained the reactions of every panel weight, the stresses were calculated for various loading, both with, and without snow, and the maximum stresses obtained for all cases. The method of Sections was used exclusively in this work. The method furnishes a ready means of ascertaining the position of counters, and the character of stresses.

Comparison was made with the amount of material in the structure, and, as a general thing, was found to agree well with the calculations. There was, however, one marked exception to the above, and this occurred in the middle bay, where the

upper chord was considerable in excess, and the diagonal ties one half the requisite size. The floor-beams were tested for the maximum moments and shears, and found to contain sufficient material.

The maximum intensity of shearing stress on the web was calculated, and compared with the safe working intensity, given by Gordon's formula. The floor-beam hangers, and the intensity of stress on the wooden stringers, were also calculated. Lastly the weight of the bridge was computed, the result proving somewhat smaller than the assumed dead load. Two sheets of tinted drawings accompany this thesis, the one showing plan and elevation, the other showing end view and details of construction.

On the Haverhill Highway Bridge. Abstract by the author, H. B. Wood.

The bridge consists of five spans in all; one pivot draw of about one hundred and twenty-five feet span; three spans of about one hundred and seventeen feet each; and two spans of about one hundred and two feet each. Each span consists of two principal trusses built after the "Pratt" model.

The roadway is twenty-five feet wide in the clear, and is supported by "built up" cross girders, each of which projects by the vertical posts, so as to form supports for the two sidewalks, which are six feet wide in the clear.

These cross girders are bolted to the vertical posts, and rest upon plate-iron brackets rivetted to the same. The upper chord is built of wrought iron plates and angle-irons, forming a rectangular cross section, open and latticed at the bottom, so as to be easily painted. The lower chord consists of flat bar iron of uniform depth, and increasing in thickness toward the centre of the span. The posts are I-beams rivetted to the upper chord and resting in bearing blocks on the lower chord. The diagonals consist of square and round bar iron with screw ends, and fastened with wrought iron forged nuts, which rest upon

cast iron bearings or angle blocks on the top chords, which abutt against the thrust plates. The "effective" section for use in calculating stresses is taken at the foot of the threads. The cross girders camber six inches in the centre, to form a water shed for the roadway, and are four feet deep at the centre. The cross bracing consists of the cross girders as compressive members, and diagonal tie rods.

Stringers of southern pine (3″ x 12″) are placed upon the cross girders about sixteen inches from centre to centre, and upon these rests a planking of yellow pine two inches thick, and running transversely. Upon this is laid a course of white oak plank, also two inches thick, and butted on the centre line of the driveway, and thence running 45° each way right and left, with this centre line.

The sidewalks have but one course of planking, and are four inches higher than the driveway. The draw is built upon the pivot plan, in which nearly the whole weight is thrown upon the centre pintle, which is adjustable. It has a spider wheel and radial rods, with coned cast-iron wheels upon their ends, running between two coned surfaces on the pier and bottom of turn-table. It is opened by means of a turning bar which fits upon the vertical shaft at the centre.

The bridge is designed to carry a moving load of twenty-six hundred pounds per foot of span, without straining it more than one-sixth of its ultimate strength.

Counters are put in where it is necessary to resist the action of partial loads.

A complete calculation of the stresses in each piece of the first span is given, also the areas of cross sections required, and the actual areas given.

Direct measurements of the structure itself were made, to obtain the latter data.

DEPARTMENT OF MECHANICAL ENGINEERING.

A Mechanical Laboratory. Abstract by the author, A. D. Blodgett.

In this thesis I have endeavored to call attention to the following points, viz.: 1. The necessity for a more extensive Mechanical Laboratory in the city of Boston. 2. Why it is a necessity. 3. What class of people would be benefitted by such an institution. 4. What Institutions in this country and abroad already have in this direction. 5. What they hope to have in the future. 6. What the Massachusetts Institute of Technology already has toward a Mechanical Laboratory. 7. What I think would be a good direction for the development of our Laboratory. 8. Why?

The above points it will be observed are taken up in more or less detail as it has been thought necessary, and I would say that I have copied freely from works on engineering both in our own land and abroad, always making a note of the same and giving the authority for the information in the margin opposite. I have illustrated the thesis with wood-cuts and photographs kindly furnished by the manufacturers of such machinery as will be found mentioned in the text.

Reference has been made to the views whenever it was thought necessary. In the basement room at the Institute represented on Plate II, I have thought it advisable to arrange machinery as there represented. This machinery will be found to consist of Lathes, Planers, Milling Machine, Saws, Drills, Emery wheel, Grinding apparatus, Testing machine, etc.

The power necessary to drive the machinery would be supplied by a belt from the Harris-Corliss Engine described and represented in the thesis.

The width of the belt is also calculated. It passed from the fly wheel of the engine to a large pulley on the main shaft which enters the room above and near the door parallel to Boylston St.

The power would be carried to each machine as represented on Plate II by a belt from the main shaft to a counter shaft for

that machine. The speed of each machine would be adjusted to the speed of the main shaft by the relative size of the pulleys. There is also for each *lathe* a set of cone pulleys which allows certain variations from the main speed.

In reference to the drawings it may be well to state that the scale for Plate I is $1\frac{1}{2}$ inch $=$ 1 foot for all parts of the calorimeter except the figures A and B, these are not drawn to scale. The scale for plate II is $\frac{1}{2}$ inch $=$ 1 foot.

Steam Boilers. Abstract by the author, C. L. Dennett.

The writer's idea in the selection of the subject was, that by giving it the study required in order to present it in thesis form, he would gain a knowledge of the subject that would be practical and useful, and which should be first possessed by the steam engineer, since the subject of steam generation naturally precedes that of steam using.

Various works have been examined in order that the best information on each point might be obtained. Personal observation has also been a material aid.

Among the works consulted may be mentioned, Burgh on "Steam Boilers," Isherwood's Experiments, Wilson on "Steam Boilers," Trowbridge's "Heat and Heat Engines," Bournes' "Catechism of the Steam Engine," Rankine's "Steam Engine," C. Wye Williams on "Combustion and the Prevention of Smoke," W. R. Johnson on the "Practical values of American and Foreign Coals," "Journal of the Franklin Institute," "Master Mechanics' Reports" and others, besides numerous pamphlets on boilers and boiler tests.

The different parts of so extensive a subject are, in the thesis, necessarily presented very briefly. The general heads are as follows. 1. The requirements with which boilers should comply. 2. General form. 3. The natures and strengths of the different materials entering into boiler construction. 4. The strength and construction of the component parts, as the shell, flues, rivets, stays, tubes, etc. 5. The boiler fittings, as grates, furnace doors, pressure gauges, safety valves, blow-off

pipes, gauge cocks, manholes, mudholes, etc. 6. The testing is considered. 7. The boiler setting and general proportions, including chimneys. 8. Boiler management, and injuries to which they are especially liable. 9. The circulation. 10. The subject of incrustation is taken up more fully than any of the previous subjects. The most common injurious ingredients of water are mentioned and different methods of preventing their action upon the plates explained. 11. The subject of combustion is also quite fully taken up. The process of combustion is analyzed; the causes and the waste of imperfect combustion, and the importance of air admission above the fuel are explained. These divisions are more or less fully illustrated by drawings, tracings, and wood cuts. 12. Land Boilers — A — the factory horizontal tubular, the vertical tubular, the fire-engine boiler, the locomotive boiler, and one of the boilers of the Hope Pumping Station at Providence, R. I. These boilers are illustrated by practical examples and the best authorities are cited as to their leading dimensions. B — sectional boilers are illustrated by cuts of the Root, Allen, Phleger, Lowe, Blanchard, Harrison, Wiegand and Exeter. 13. Marine boilers. The results of Isherwood's comparison of the Martin vertical water tube and the English horizontal fire tube boiler are illustrated by outline drawings of these two classes. A complete tracing of a boiler of the U. S. Steamship Vandalia is given and the principal data of its design. Two boilers, one of the U. S. Steamer "Jacob Bell," and one of the U. S. Steam Battery "Monitor" are illustrated by tracings, as being boilers of high efficiency, and the results of Isherwood's experiments on each are given.

Certain Points in the Development and Practice of Modern American Locomotive Engineering. Abstract by the author, Francis E. Galloupe.

In the study of the Locomotive Engine the subject divides into what are called the theoretical and practical aspects. I may therefore in its treatment first view the practical division

and state what has been accomplished before applying the theoretic principles by which to criticise what the latter has done. In the treatment of the former, an investigation of the efficiency of the locomotive as it exists, has been made. The locomotive is throughout an exhibition of Dynamics, a moving structure. It begins with receiving power as the motion of heat, from the combustion of the coal, and ends with imparting force and producing visible motion of masses of matter. In the fuel from which this is derived, the energy is stored. The primary moving force in the locomotive, heat, is first considered and the manner and amount of its generation in the combustion of coal. The efficiency of the working fluid to which this energy is transferred, succeeds. The efficiency of the apparatus by which this is effected is next ascertained, and that of the mechanism by which the portion of energy utilized in the former is converted into its final form of motion against resistance at the circumference of the wheels. The subject is therefore considered under the following heads: —

In a historical sketch are traced the successive improvements in the development of the Locomotive and the Railway, and the practice with regard to the former from Darwin's "Fiery Chariot" and Cugnot's first actual running locomotive machine, in 1769, to the present time. The performance of these early engines is given and the most important improvements and principles developed in them are stated.

Part 1. The Production of Heat and the Laws of Combustion. The various sources of heat, mechanical, physical and chemical are mentioned, and that of Chemical Attraction, the action of which between elementary substances in the fuel and the oxygen of the air produces combustion, considered. The natural and artificial solid combustibles are stated, and three typical substances employed in locomotives, viz.: — Anthracite Coal, (Lackawanna), Semi-Bituminous Coal, (Cumberland), and Wood, (Dry Pine), considered. Tables showing their composition are given and calculations made of one, Cumberland coal, as follows: — its total heat of combustion, equivalent carbon in

one pound, evaporative power from 212° and 62° Fah., equivalent foot-pounds of work, weight of air necessary to be supplied for complete combustion and for dilution, and the temperature of the fire. In this part it was found just what the fuel that is burned in the fire-boxes of locomotive boilers is, by theory, capable of doing.

Part 2. Water and the Properties of Steam. Of the two distinct operations common to all heat engines, heat making and heat expanding, in the former of these the facts having been ascertained, the latter is here considered. Water is treated chemically, physically and dynamically. The physical properties of steam are enumerated and the subject discussed with reference to three circumstances which determine its condition, its density, pressure and temperature. One pound of saturated steam at atmospheric pressure, at 120 pounds and 140 pounds above the atmosphere, is treated in its generation under constant pressure, and also under volume, its motive power, expansion, condensation and efficiency.

Part 3. An American Passenger Locomotive. The ultimate object of the locomotive-engine is to draw a train of a certain number of cars, upon a specified maximum up-grade, at a certain velocity. In this part a bituminous coal burning passenger engine, built at the Hinkley Locomotive Works in October, 1875, for the Eastern Railroad, was selected, illustrated by five detail drawings and a complete specification given. Its parts were classified and its details and action discussed under the following heads: —

A. The Boiler. 1. The shell, description, construction, material, strength, factor of safety. 2. The Heating Apparatus, the furnace and the tubes. The efficiency of the heating surface and furnace is found and other calculations made concerning its evaporative power. 3. The Feed Apparatus for the supply of water to the boiler consists of the pump and injector. These are described, illustrated by tracings, and the principle of the latter explained. 4. The Safety Apparatus which forms a large part of the locomotive boiler fittings, is mentioned in

detail, and the Steam Gauge and Safety Valves illustrated, described and their mode of construction and principles upon which they operate given. 5. In the Transmission Apparatus by which the power is distributed to the engine, the steam and exhaust pipes are treated and the velocity of steam through them determined.

B. The Engine. In the engine the parts and topics are mentioned as 1. The Cylinder and its proportion; 2. The Valve Gear; 3. The Action of Steam in the Cylinder and the Blast; 4. The Transmission of Power to the Wheels by means of the Cranks and Connecting Rods; 5. The Running Gear; and 6. The balancing of the engine.

In this part the object was to apply theoretic principles to this particular engine and determine what its performance should be. In the succeeding part it is ascertained how nearly it does approach to this theoretic excellence and its actual efficiency determined.

Part 4. Trial of an American Passenger Locomotive. On March 14–18, 1876, trips were made upon the engines of two of the fastest passenger trains of the E. R. R. On the first and last of these days I rode from Boston to Rockport, a distance of thirty-six miles, and return, upon engine No. 36 ("The John Howe"). Upon the three intervening days trips were taken to Portsmouth, N. H., a distance of fifty-six miles from Boston, upon the 8.30 A. M. Bangor train, and data taken upon them concerning the actual running of the engine.

The engine was No. 55, being the same as that whose parts are discussed in Part 3. Six tables give in full the data taken upon the latter and results obtained. The observations made were the times of passing all the stations, the steam pressures, the point of cut-off, the coal consumed, the depth of water in the tank, the speed at different portions of the road upon levels, up-grades, curves and against head winds, and miscellaneous notes of the time of stopping, the action of the air-brake, the oiling of the engine, the weather, condition of the rails, direction of the wind and number of cars. In all, records of four

hundred and ninety-five miles run were hauled and of the engine under consideration three hundred and thirty-six miles. In brief, it was the aim to note every occurrence that took place with regard to the engine. The carrying of a train from Boston to Portsmouth means so many gallons of water and pounds of coal consumed. The tables state what these amounts are. From them other results are calculated, such as the equivalent horse power exerted and the train resistance. The record of the direction and velocity of the wind during these three days was obtained from the Weather Signal Office in Boston, so that the extent of the resistance from this cause could be approximately ascertained at any part of the road. The method of correcting the times for the rate of the watch is explained, the action of the safety valves and method of determining the coal record and of the speed. The capacity of the tank is calculated both from the measurements upon the detail drawings and from actual measurements with a steel tape, of all the accessible parts. A drawing of the tank and its internal staying is given.

Succeeding is a discussion of the peculiar facts shown by these records, and a table is given of the performance of eight engines of the E. R. R., including No. 55, for the month of January, 1876, by which any deviation from the records of ordinary locomotives is plainly seen. The power exerted by this locomotive on a part of the road is next calculated; its weight and tractive power ascertained. The extent of the train resistance is partially discussed. Finally, the efficiency of the mechanism is approximately found.

To sum up, the efficiency of the locomotive is the product of the three factors found and is stated as follows:

1. Efficiency of Furnace and Boiler, ...557
2. Efficiency of Steam, ...071
3. Efficiency of Engine or Mechanism, ...80

Efficiency of the Locomotive Engine, $.557 \times .071 \times .80 = .326$ or three and two-tenths per cent.

The projects of improvement in the boiler, the mechanism,

and in the use of steam are mentioned, and statements made as to the effect of gauge upon economy in locomotive use. Narrow gauge roads, having the United States Standard gauge of three feet, are rapidly being opened in our State, and to them we look for cheap passenger transportation, rapid speed and economical working.

Paper Mills and Machinery. Abstract by the author, S. Hollingsworth.

After a brief history of the first paper mills in Europe and America, the subject is divided into, and taken up under two principal heads: First the Machinery, and second Mills.

First. The various machines are treated under the heads of the different processes they aid. The processes themselves however are treated only so far as concerns the engineer who designs the mill.

The manufacture of paper from the most commonly used material generally requires the following.

1. To form the pulp from the raw material. Thrashing, sorting, dusting, boiling, washing, draining and beating are generally necessary, and under all these heads, the machines and apparatus are described and shown in sketches, etc. The speed and power required by the most important of them is given. The general arrangement of foundations and rooms that contain them is spoken of. And in the case of the boiling process, results are given of an experiment by the author to find the amount of steam used that the engineer may know what boilers must be used.

2. To form the pulp into paper. The old process of making the paper by hand or from the vat is still practiced in Europe, and is therefore described and a sketch given of some of the apparatus used.

Paper is now formed from the pulp by the so called "paper machine" in some form. Of these there are two kinds in common use, the Fourdrinier and the cylinder machines. The history of the development of the Fourdrinier machine is quite

interesting, and is therefore briefly given. The two machines are described and illustrated, their comparative merits are spoken of; and the questions of amount of steam used in drying the paper by an experiment by the author; the foundation of machine; the room; ventilation; felt-washers; roll-grinders, etc., are brought up.

Second. Under the head of Mills the question of location brings up the questions of communication with the markets; the use of steam or water for power; the quality and quantity of water used in the manufacture; building materials, etc. The whole power required by a mill of a given capacity is given, and also something about the general arrangement of the mill, repair shop, etc.

Pumping Engines. Abstract by the author, Alfred C. Kilham.

Dividing pumping engines into two classes, according as they pump into a reservoir or directly into the distribution, I have first described several engines under each head. Under the head of Engines pumping directly into the distribution, I have taken the Corliss and the Holly engines and the new engine recently erected at Providence, according to the designs of Mr. A. F. Nagle of that city, and have endeavored to give some idea of their size and character, together with their advantages and disadvantages as regards economy and liability to accident. Under this head are also compared the advantages and disadvantages of the two systems.

Under the head of Reservoir Engines are taken, first, the Cornish; second, the Leavitt, as an example of a beam and fly-wheel engine; third, the Worthington. These are described like those under the first head, the advantages and disadvantages of each variety of engine being pointed out, and a table of the duties attained by each kind of engine being given.

Under the head of Cornish Engines is described "Davey's Differential Valve Gearing," which has been quite extensively ntroduced in England both for Horizontal and Cornish pump-

ing engines. Its object is to make the valve motion not entirely dependent on the piston, but partly on the load, and so to change the point of cut-off that the speed of the piston shall not be very much accelerated or retarded by a change in load, and thus to ensure freedom from accident.

Having described engines under both heads, a comparison is drawn with regard to ultimate economy between the two systems and between the different engines in the same system. From calculation the engines pumping into the distribution are decided not to be economical except for places where not more than 2,000,000 gallons per day at the utmost are required.

From a similar calculation of the first cost and duty of different engines, it is decided that the Leavitt beam and flywheel engine is the most economical engine in this country, it having given both the highest special test duty and the highest annual duty of any engine in this country. On the special test the duty was 103,923,215 foot pounds per 100 pounds of coal consumed, and an annual duty of about 90,000,000 foot pounds per 100 pounds of coal consumed, including coal used for banking, has been obtained.

The Worthington engine, which has been largely introduced throughout the United States, is much valued on account of the apparent ease and quietness with which it performs its duty and its freedom from liability to serious accident; but although it gives good results compared with most pumping engines, it does not approach the Leavitt engine in economy.

Shafting and its Fittings. Abstract by the author, Theo. J. Lewis.

In my thesis I have endeavored to give an account of a research which I have made into the subject of Shafting and its fittings. In this research I have read such books and essays as were at my command, and have taken from them what seemed to me to be the most important facts connected with the subject.

The sources from which the information contained in the

thesis is chiefly drawn are the following: Rankine's "Machinery and Mill work," Weisbach's "Mechanics of Machinery," Fairbairn's "Mills and Millwork," Box's Mill Gearing," Barlow's "Strength of Materials," Anderson's "Strength of Materials," Essays upon Shafting by Messrs. Allen, Hussey, Burke and Francis in the Report of the New England Cotton Manufacturer's Association, Essay upon Shafting by Mr. Coleman Sellers, "Fittings for Line Shafts" in the Engineering.

The subject is treated of in the following manner: —

1. The older forms of shafting and the various improvements which have been made upon them, as the introduction of lighter shafts and pulleys and the general adoption of belting as a mode of transmission of power.

2. The materials from which shafting is constructed and their adaptability to the purpose; giving a series of tables collected from various sources, showing the transverse and torsional strengths of the metals, steel, wrought iron, both hot and cold rolled, and cast iron. Also showing the methods by means of which these strengths are calculated.

3. The size of shafting, showing the demonstration of the general formula for the diameter of a shaft, and giving the values of the constants in those formulæ as used by different practical men. Stating the arguments for and against the use of very light shafting, and some examples of sizes which have been or are now in daily use.

The fourth general division of the subject comprises the fittings for shafts. The fittings discussed are, — Couplings; one of the first requirements that a line of shafting may run well being that the various sections shall be firmly coupled together. The requirements of a good coupling are given, and also examples of various forms in use.

Bearings; giving examples of the best forms of hangers and pillow blocks. Treating of the proper distance between two bearings, and of the metals of which they are made, and the proper pressure per square inch of bearing surface. In this connection the proper speed for shafts is spoken of.

Pulleys; the forces which act upon them; the shape and number of arms; rules for the crowning. Belting; the materials of which it is commonly manufactured, mode of fastening. The strength and the proper speed at which to run belts.

Efficiency of Marine Engines. Abstract by the author, Chas. T. Main.

The steam engine is a machine in which heat is converted into work with a certain amount of efficiency. During this conversion there are successive losses. 1. The whole of the heat from the fuel is not utilized in producing steam. 2. All the heat in the steam is not converted into work on the piston. 3. There is loss by the friction of the mechanism. The *second* and *third* factors are developed in the thesis.

1. On the different methods of using steam.

Although in some engines the expansive working of steam does not indicate a gain, yet in the modern engines the gain is worthy of notice. And the allies of the use of steam expansively are "Superheating," "The Steam Jacket," "Compounding," "High Steam Pressure" and "High Piston Speed." As a general thing now-a-days, too much expansion is attempted, and thus the results are not so economical as they ought to be. With the steam jacket and superheated steam the expansion can be carried on to a much greater extent than without, for these agents are preventions of surface condensation which is the great evil of the expansive use of steam, and the gain from their use is well worth studying. As far as the theoretical working of the steam goes, it makes no difference whether the expansion takes place in one cylinder or in a succession of cylinders; but as the size of the parts depends upon the *greatest*, and not the *mean* strain, the more expansively the steam is used the less is the *mean* pressure. Now to avoid the making of the parts so large as to increase the expense and friction, the compound engine was invented, and it has truly fulfilled the object aimed at. The parts connected with the low pressure cylinder are of more slender construction than when a single

cylinder is used. It is well known at present that high pressures, and high piston speeds are conducive to economic results.

2. On the Various Combinations of Mechanism.

The size and proportion of the engine is governed by the work which it has to perform and the instrument by which it does it. In the case of paddle wheel engines, a long piston stroke and a short arm crank on the same shaft with the wheel is conducive to speed, power, and durability. For paddle wheel engines, probably the old fashioned working beam and its connections is as satisfactory as any method of transmitting the power from the piston to the crank. It has stood the test for many years, and is now much used for river and coasting purposes. The side lever engine has been used with success for ocean steamers, but its bulk and heaviness requires it to give way to the smaller and lighter engines, such as the oscillating, the trunk, and other engines having direct connection; the oscillating engine is to be preferred to the trunk on account of its lightness, strength and durability, and its accessibility for repairs; it has come into universal favor.

But the greater economy and greater convenience of the screw vessels have caused the paddle wheel to become almost extinct for ocean and war purposes. There are various types, the most common of which are, the geared, the oscillating, the horizontal, the vertical and the inclined. The shaft of the geared engine is divided in a clumsy way, and since it is now known that high speed is economical, and for other reasons, the direct acting engine is considered as the *screw engine proper.* All the other forms have been used to good advantage, according to the purpose to which they were applied.

Whatever form is used there is a great saving by the use of the surface condenser instead of the jet condenser, and all the other details should be arranged with reference to their simplicity, durability, and access for repairs. Of course in selecting an engine judgment must be used, and attention paid to the efficiency, the location, price of fuel, etc.

In writing this thesis, the author has gathered information

from all the experiments at his command, and which he deemed sufficiently accurate to make use of. Under "Expansion" experiments of Isherwood, and those made at the U. S. Navy Yard in Boston, on the "Rush," "Dexter" and "Dallas," also those made at Baltimore on the "Bache" were referred to, and results given. Under "Superheating" those experiments made by Mr. Isherwood on the "Georgianna," "Adelaide," and "Eutaw" are given in synopsis. In studying the effect of the steam jacket, the experiments on the Brooklyn Pumping Engine, and those at the Navy Yard were referred to and results given. In determining the effect of compounding, and the gain of high steam pressure these last named were also used. A synopsis of the experiments made on the U. S. steamers "Spencer" and "McLane" to determine the relative efficiency of the screw and paddle wheel is given.

The Screw Propeller. Abstract by the author, C. F. Prichard.

Although spoken of and suggested by various authors it was not until 1836 that any extensive attempt was made to use the helicoidal or screw surface as a means of propelling vessels; then the idea was taken up in England simultaneously by Mr. F. P. Smith and Capt. John Ericsson. The exertions of either of these would have achieved a success, but the rivalry which existed hastened its introduction. Smith's form consisted of a single threaded screw of two convolutions, and was the same in principle as the true screw now in use. Ericsson's form consisted of two hoops revolving in opposite directions having short blades placed upon their circumference. The thesis contains detail drawings and descriptions of both these forms and short descriptions of numerous other forms.

The rapid rise of the propeller into general use is due principally to its power of being combined with sails, its form and the arrangement of its engine being such that it does not interfere at all with the working of the sails, while it is almost impossible to combine steam with canvas in the paddle wheel

vessel; beside this reason there are many others which are given, with contrasts between the speed of the two classes of vessels.

Under the head of the generation of the helix and helicoidal surfaces are given the definitions of, and the manner of describing and drawing the various forms of true, axially expanding, and radially expanding screw surfaces. The radially expanding, and what is called the bent back form of blade, have for their object the overcoming of the centrifugal action of the screw. A particle of water struck by a straight bladed screw is acted upon by two forces, a centrifugal force tending to drive the particle radially, and the propulsive effort resulting from the oblique action of the blade; the resultant of these two tends to drive the water from the screw in the shape of a frustrum of a cone. If this body of water could be driven aft in a cylindrical column we should utilize all the force, and to do this the blade is radially expanded or more commonly bent back. This question is discussed and a formula for the true curve deduced.

The proper form of the screw depends entirely upon slip or the recession of the water, for it is evident if there were no recession of the water we should have the case of a screw working in an immovable nut, and provided the blades were strong enough, it would make no difference whether we have one blade or four, short or long length, large or small diameter; if the pitch and number of revolutions were the same the propulsive effort would be the same; but the water does recede and hence slip must be taken into account, and it becomes necessary to choose the particular dimensions which will reduce slip to a minimum. Slip cannot be entirely done away with owing to the nature of water; the pressure of a surface against the water puts it in motion, and this motion is a measure of the resistance, accordingly although slip is an evil and occasions losses from many sources, it is a necessary one and should be regarded as a purchase of power rather than an entire loss. After discussing slip the proper dimensions of the screw are given with the reasons for choosing them, as deduced from experiments by Isherwood, Mall & Bourgois, and others.

When steam is used as an auxiliary power it is often advantageous to proceed under sail alone; in this case the screw must either be hoisted or must drag in the water. This dragging causes an important resistance, and I have given the experiments of Isherwood upon the resistance of dragging screws as determined by dynamometrical measurement.

When sailing for some time this resistance becomes a considerable amount and may be obviated by the methods of hoisting the screw out of the water; several of these methods are described and illustrated.

The two methods of making a casting of a screw, that by sweeping up a mould, and that of making a wooden pattern are described.

The principal forms of screws in use in this country are the True Screw, the Griffiths, the Hirsch and Isherwood's form; these forms are described and working drawings given, taken from actual examples now in use in the English and American Navies. The Griffiths screw is a tracing of the form of screw applied to the Great Eastern.

The Mungin and Lowe-Vansittart propellers are described, though they are used more particularly in France and England.

The resistance of a vessel is composed of Head and Skin Resistances; a method of determining this resistance is given, with the manner of finding the power of engines necessary to drive the propeller, and several methods of receiving the thrust.

DEPARTMENT OF MINING ENGINEERING.

The Port Henry Iron Industry. Abstract by the author, C. F. Allen.

Part 1. Geographical location and description of the region. Geology of the country. Discovery and development of the mines. Growth and progress of the iron industry. General situation and its advantages.

Part 2. The mines. Their number, location, history and remarks. The Cheever bed — a detail description of the mine, showing location, situation, giving manner of working,-winning ore, hoisting, lighting, ventilating, materials used, drainage, pumping, timbering, tramways, inclines, surface works, machinery, railroads, sorting, dumping, labor, yield, wharves, shipment, etc. Other beds — their history and brief descriptions.

Part 3. The blast furnaces; their history and growth. The Bay State Iron Company's Furnace, with detail description of the works and working of the furnace. Statements of the amounts of different materials which go in and come out of it, and the relative proportions of charges, fluxes, ores, fuel, etc. Analyses of the ores, fuel, fire-brick, limestones used at the furnaces, and of the slag and pig produced. Table of analyses of five different pigs and the results deduced, etc. The description, in brief, of the Cedar Point Furnace.

Part 4. Comparison of this with other regions, particularly that of Lake Superior, and the cost of mining and shipping ore. Comparison of these and other furnaces. Advantages and disadvantages of the region.

Part 5. Chemical Work. Methods of analysis. Stating the method used with brief description. The reasons for so doing and results obtained.

The Metallurgical Treatment of an Argentiferous Galena from Burleigh Tunnel, Colorado. Abstract by the author, S. James, Jr.

The subject is treated as follows:

1. Position of the tunnel and purpose of working. Progress of work and number of lodes cut. Geology of the tunnel.

2. Composition (both mineral and chemical) of the ore worked.

3. Crushing, sampling and weighing of the ore.

4. Roasting. Effects of zinc blende and chemical changes the ore undergoes. Roasting furnaces. Time and coal used, and losses in lead, sulphur and silver.

5. Trial of the Flintshire process.

6. Separation of the lead from the ore by the blast furnace. Analysis of the tap cinder used for fluxingwith a calculation of slag and charging mixture. Size of blast furnace used, and the construction of the hearth. Working of the operation and blast. Tables taken of the charging and tapping. Amount of coal used. Regulating the amount of coke. Sorting and working over the products of this run to be used in a second run, or for getting the lead ready for refining. Changes before second run, new tuyeres in the furnace, and a forehearth used. Action of metal matte and slag. Tables of the charging and tapping at the second run. Separation of the lead in the forehearth, but no slag sample. Loss of lead in the whole operation and amount of fume.

7. Getting a slag sample by fusion. Manner of using a plumbago crucible.

8. Refining of lead under charcoal. Tables of the running of the furnaces, coal used, and loss of lead.

9. Sweating to get rid of copper and impurities in the lead. Description of the heater and manner of working.

10. Smelting of the copper and impurities with galena to get the copper into a matte. Time, and coal used.

11. Zincing. Parke's process. Zincing and sweating three times with one per cent. of zinc each time, by which means the amount of silver in the lead was reduced to .001 per cent.

12. Distilling off the zinc from the silver lead.

13. Cupelling. Tables of losses in the different operations.

The Richmond Blast Furnace. Abstract by the author, Thos. W. Robinson.

After a brief history of the furnace the details were considered under the following heads.

1. The Construction.

2. The Accessories and Machinery.
3. The Manner of Working.
4. The Results of Chemical Analysis.

An Investigation and Report on The Pomeroy Iron Works at West Stockbridge, Mass. Abstract by the author, Theo. E. Schwarz.

I visited the Pomeroy Iron Works last September, spending one week in studying the works and mines in the vicinity, and in collecting samples for analysis, and obtaining data for this thesis. The works consist of an anthracite blast furnace and accessories. I have considered the subject under the three following heads:—

1. The Works.
2. The Process of Manufacture.
3. The Manufacture Economically considered.

Under the first head, I have described, with drawings, the blast furnace, blast heating stove, engines, incline, etc., and the mines of brown hematite ore situated in Berkshire county, from which the furnace derives part of its ore supply.

Under the second head, I described first the process of washing the limonites, as practised in Berkshire county. The apparatus, of which I have given a drawing, consists of three revolving cylinders, through which the ore passes with water. The apparatus sizes the ore into three different products according to the sizes of the perforated plates composing the cylinders. I then described the five ores; the sampling; preparation for analysis; method of analysis, and the analyses of the ores, flux, and coal.

The following are the analyses:—

	PORT HENRY MAGNETITE.	ANDREWS-BROWN HEMATITE.
Insoluble Residue	3.54	14.16
Binoxide of Manganese	.88	.36
Alumina	1.20	1.46
Ferric oxide	90.01	73.80
Phosphoric acid	2.82	.49
Sulphur	tr.	—
Loss on Ignition	—	9.72
Lime		tr.
	98.45	99.99

CALEDONIA RED HEMATITE.		LEETE ORE ("WHITE HORSE").	
Insoluble Residue	10.57		20.80
Binoxide of Manganese	.23		2.96
Alumina	2.22		.76
Ferric oxide	72.15		56.30
Phosphoric acid	.43		.25
Loss on Ignition	8.09		16.80
Lime	4.49		
Magnesia			.42
Sulphur	—		—
	98.18		98.29

CHESHIRE BROWN HEMATITE.		LIMESTONE FLUX.	
Insoluble Residue	15.43	Silica	2.92
Binoxide of Manganese	1.13	Protoxide of Iron	.40
Phosphoric acid	2.13	Lime	42.83
Alumina	2.13	Magnesia	9.65
Ferric oxide	68.67	Carbonic acid	44.235
Loss on Ignition	10.00		
Sulphur	—		
	99.49		100.035

LEHIGH ANTHRACITE. (Very pure specimen.) The ASH contained:—

Volatile matter	11.16	Alumina	3.59
Ash	6.85	Silica	3.28
Fixed carbon	81.98	Lime	tr.
Sulphur	.0062		
	99.9962		6.87

I next gave descriptions of the operations of charging, drawing slag, casting, etc. The analysis of the slag is as follows:—

SLAG.

Silica	37.62
Alumina	12.84
Ferrous oxide	tr.
Lime	39.16
Magnesia	6.98
Protoxide of Manganese	.65
Sulphide of Calcium	2.16
Alkalies	1.11
Phosphoric acid	tr.
	100.52

The three grades of pig iron analyzed as follows: —

	I.	II.	III.
Carbon combined	.53	.585	.395
" graphitic	3.38	3.49	3.36
Phosphorus	.84	.875	
Manganese	.89	1.13	.62
Sulphur	.016	.015	
Silicon	3.24	2.16	4.44 = Silica.
Slag	.20	.116	
Iron (by difference)	90.904	91.629	

Then follows a general statement and description of one week's run of the furnace, and comparative results deduced from the analyses and actual working data of the furnace.

Under this head the following points were considered: —

1. Calculation of the theoretical slag from the analyses, with its formula.
2. Calculation of formula of slag actually obtained.
3. Weight of obtained slag.
4. Calculation of amount of pig iron expected in one day, from the analyses of the ores, and comparison with amount actually obtained.
5. Composition of the most desirable slag.
6. Comparisons with other furnaces.

Under the third division of the subject, I have added up the expenses and receipts for the week ending Sept. 9th, '75, and balanced accounts, showing a loss of $ per ton of iron made. The question of greater economy of production, as affected by the ores used, has also been discussed, and whether it would be well to attempt the production of Bessemer pig. In which case, what would be advisable ores to use?

On Newburyport Silver Lead Mines. Abstract by the authors, J. H. Susmann and W. D. Townsend.

This abstract is made to embrace two theses on the same subject, which was too extensive for one person to do justice to it in the limited time.

We have given in our theses general accounts of the history, development, mineralogy, and geology of the Newburyport district; in addition to a description of the treatment by us of two ores from the Chipman lode, a rich float ore, and a poor third grade ore.

Our first experiments were on the concentration of 3d grade ore. For this purpose 1628 pounds of ore, yielding to analysis 9 per cent. of lead, .03 per cent. of silver, worth all told $18 to the ton, were taken and treated in the wet way by a system of spitzlutten, jigs, side and end bump tables, and cones. We obtained a concentration of 233 pounds, containing 73½ per cent. of all the lead, and 54.7 per cent. of all the silver in the ore, together with a slime containing 10 per cent. of all the silver. These products were both of them ready for smelting. The concentration yields to analysis 46 per cent. lead, .115 per cent. silver, worth $94 to the ton. Silver being valued at $1.15 currency and lead at 6 cents per pound.

For the metallurgical treatment we took 774 lbs. float ore, which was a little poorer than the present first class ore. It yielded to analysis 44.30 per cent. lead, .15 per cent. silver. This was treated for the lead, silver and copper by roasting, agglomerating, and subsequent smelting in the blast furnace; yielding a crude lead containing silver and some copper, and a copper matte.

As a result of the smelting, we obtained products (lead and matte), containing 234 lbs. lead, 16 oz. of silver, 0.256 oz. gold, and 5 pounds copper.

The silver and gold were subsequently extracted by Parke's process, followed by cupellation. The copper was left in the matte, from which it can be readily extracted by wet processes.

The details of this work are fully given in the theses.

DEPARTMENT OF CHEMISTRY.

Action of Tungstic Acid upon Gelatin. Abstract by the author, Wm. P. Atwood.

I have considered the subject of my thesis under the following heads:

1. Object of thesis.
2. Gelatin.
3. Tungstate of soda.
4. " acid.
5. Method of determining Wl_3 and analyses of tungustate of soda.
6. Method of preparing the substance produced by the action of tungstic acid upon gelatin.
7. Properties of substance so produced.
8. Method of analysis.
9. Results of analysis.
10. Comparisons and conclusions arrived at.

On Anthracene and Associated Hydrocarbons. Abstract by the author, Chas. R. Fletcher.

This consists: —

Part 1. A digest of published papers on anthracene, anthraquinone, alizarine, phenanthrene, and their derivatives.

Part 2. Experiments made to determine the value of the various methods proposed for the quantitative determination of anthracene;

Experiments on the quantitative determination of phenanthrene.

The Action of Chloride of Sulphur upon Spirits of Turpentine. Abstract by the authors, Albert H. Low and Charles N. Waite.

The subject is treated under the following heads:

PART FIRST, BY ALBERT H. LOW.

Chapter I. 1. The action of chloride of sulphur upon certain oils, etc.

2. Extract from Parke's patent for the vulcanization of caoutchouc.

3. Treatment of the spirits of turpentine with chloride of sulphur, and separation of the products by distillation.

Chapter II. 1. Separation, purification and analysis of a substance having the composition $C_{10}H_{16}HCL$.

2. Determination of the composition and physical properties of other products.

3. Summary of the results of the investigation.

PART SECOND, BY CHARLES N. WAITE.

Chapter I. General remarks on the methods employed in obtaining the various products.

Chapter II. Purification and analysis of a sulpho compound and speculations as to its molecular structure.

Practical Estimation of the Value of Tanning Materials, together with Points on Tanning. Abstract by the author, Wm. E. Nickerson.

The work done may be divided as follows:

1. Collecting together some of the more available methods for the estimation of *tannic acid*, which have been published in foreign and American scientific works.

2. Consideration and trial of some of the more promising of these methods, by which one was found which can be used quickly, and by persons possessing but very little chemical skill. The method used, although essentially like the original, is somewhat simplified.

3. The determination of the value of various liquors from tanneries, of a number of the more common tanning materials and commercial extracts, by the selected and modified method, and the comparison of the results with those obtained by other chemists, with other methods.

4. The methods used by tanners, to test the strength of their liquors and tanning materials.

5. Investigation of the supposed loss of considerable quantities of tannic acid during tanning, by oxidation to gallic acid.

6. A partial analysis of an exhausted tan liquor.

DEPARTMENT OF METALLURGY.

A Report on the Vershire Copper Mine and Ore. Abstract by the author, R. H. Gould.

The first part of this thesis is devoted to a description of the mine and the method adopted for working the ore at Vershire. The second part describes the working of about 500 pounds of the ore at the Institute.

I. The ore mined at Vershire is a sulphide of copper and iron (Chalcopyrite) which occurs associated with a large amount of pyrrhotite and quartz. The method adopted for extracting the copper consists of the following operations. 1. Cobbing the ore to a uniform richness of about 9 per cent.; 2. Roasting the ore in large heaps to expel a portion of the sulphur; 3. Fusing the roasted ore in blast furnaces to obtain a matte containing from 30 to 35 per cent. of copper; 4. Roasting the matte in kilns to expel the remaining sulphur; 5. Fusing the roasted matte in blast furnaces to obtain pig copper containing 95 to 96 per cent. of metallic copper.

II. The working of the ore at the Institute is divided as follows:

1. Preliminary Treatment. The ore was first examined for the various minerals which it might contain. Those found were, chalcopyrite, pyrrhotite, quartz, blende, garnet, feldspar and mica. The first three make up about 95 per cent. of the ore.

The ore was next crushed to lumps of half inch diameter, and sampled. The ore on analysis gave the following:

Copper	12.18
Iron	34.93
Zinc	0.76
Lead	0.17
Sulphur	27.59
Silica	16.88
Ferric oxide	0.36
Alumina	1.90
Magnesia	1.54
Water	0.03
Undetermined	3.66
	100.00

2. Roasting of Ore. The ore was roasted in reverberatory furnaces for four hours, during which it lost over one half of its sulphur.

3. Fusion for Matte. The roasted ore was fused in a blast furnace, puddle cinder and limestone being used for fluxes.

The main products were, a matte containing about 25 per cent. of copper, and a perfectly fusible slag of the following composition:—

CuO,	0.56
PbO,	0.29
SiO_2,	35.97
FeO	41.90
$Ab_2O_3 + P_2O_5$,	8.55
CaO,	8.56
MgO,	1.14
Undetermined,	3.03
	100.00

4. Roasting of Matte. The matte was roasted in four charges, of 56 lbs. each, for about six hours.

5. Fusion for Black Copper. The roasted matte was fused in a blast furnace. Revere acid slag and sand being used as fluxes. The main products were:

1. Black Copper very highly charged with iron;
2. Matte containing about 44 per cent. of copper;
3. Slag which was perfectly fusible, and on analysis was found to contain no copper.

DEPARTMENT OF NATURAL HISTORY.

Catalogue of the Alcidæ in the Museum of the Boston Society of Natural History; with a review and proposed classification of the family. Abstract by the author, W. B. Barrows.

In this paper the family is first located and then briefly defined; its prominent characteristics, as shown in the various specimens in the Museum, being simply enumerated, and the more critical notice of specific and generic differences left for the descriptions of Genera and Species which immediately follow.

The descriptions are all original and are made from actual specimens in the Museum. Twenty-one species are included in the family and twelve of these, representing every Genus, are contained in the Museum. No descriptions of species have been given where actual specimens have not been handled, but each species is assigned its place in such a manner as to make a connected series which seems to best represent the natural relations of the members. One feature of the work is the reduction in the number of Genera usually admitted, only seven being here accepted; while the exclusion of sub-families is a parallel feature. These two points, involving the whole relation of species to species, are somewhat fully, though not exhaustively, discussed in the concluding third of the paper, where the grounds for every step have been carefully considered.

Two plates, containing figures of thirty beaks (both plan and elevation) conclude the paper.

The whole classification differs widely from those most generally in use; but the writer has been largely guided by such facts in the embryology of the group as have been within his reach and ability; and these facts, which have thus far been too generally overlooked, have made many of these changes imperative.

Geology of Eastern Massachusetts. Abstract by the author, W. O. Crosby.

This essay is prefaced by some remarks on the general structural features of the eastern United States.

Attention is called to the existence, during Paleozoic time, of a great gulf on the western side of the Appalachians, forming part of the interior Continental sea.

In this Paleozoic gulf is found a probable cause for the greater thickness of the Paleozoic sediments in the Pennsylvania region as compared with any other part of the Continental basin.

The general absence of Paleozoic strata from the Atlantic slopes of the Appalachians is noted, and the fact pointed out that the Paleozoic rocks of eastern North America were deposited about the western and northern sides of what is now a long and narrow belt of land stretching from Maine to Georgia. Much evidence is adduced to show that this limited area had a greater extension to the east and south-east in ancient times than now; that there must have been during Paleozoic time, where now lies the basin of the Atlantic thousands of fathoms deep, a great continent, from which were derived the detrital materials forming the Paleozoic sediments of both Europe and America.

It is shown that our Atlantic coast line exhibits two grand deflections or bays, — the Gulf of Maine lying between Cape Cod and Nova Scotia and the large nameless deflection of the middle portion of the coast between Cape Cod and Cape Hatteras. The latter, which has been christened the Alleghanian Gulf, is proved to date from the beginning of Mesozoic time and to owe its existence to the great accumulation of sediments forming the Alleghany Mts.

The Gulf of Maine, on the contrary, is shown to be far older, having been, like the Gulf of St. Lawrence, with which it formerly communicated, in existence during the whole of Paleozoic time. Its origin is found in the erosion of an anticlinal of old crystalline rocks.

The age and relations to the Paleozoic sediments on the west and the Metazoic on the east of the rocks forming the long and narrow belt of land, before adverted to, stretching from Maine to Georgia, are discussed at some length, shown to be, with small exceptions, chiefly crystallines, and to probably ante-date in their origin the earliest Primordial.

Coming to the proper subject of the paper, the relations of Massachusetts to this Eozoic belt are defined and the rocks of the State divided into two principal groups: (1) the crystalline, and (2) the uncrystalline.

The crystallines are further divided into the Norian, the Huronian and the Mont Alban. Then follows at considerable length, forming the major part of the essay, an account of the lithology, distribution and probable origin of the various rocks forming each of these formations.

The rocks referred to the Norian are identified with the Norian of other regions, and, although occupying but a small area in the Eastern part of the State, are shown to be of great scientific importance, since they are the oldest rocks in Massachusetts and perhaps in New England, and afford a key to the geology of this whole region.

The stratigraphical relations of the Norian of this vicinity to the rocks of the same and of Laurentian Age in New Brunswick is pointed out.

The rocks of the Huronian Age are divided lithologically and chronologically into several groups, which, stated in their order of sequence, are granite, felsite, diorite, and stratified rocks including limestone. These are minutely described, their lithological and stratigraphical relations pointed out, showing that they are strictly members of one and the same series, and the law governing their distribution indicated.

The derivation of the compact felsite from conglomerate is briefly treated, old views discussed and new ones advanced.

General sections across this formation from north to south are given, showing that there is a repetition of the strata which can be accounted for only by a gigantic fault which must ex-

tend from the shore in Ipswich south-westerly through Essex and Middlesex counties. It is conceived to die out near Westborough, and a reason is found here for the existence of the peculiar band of Huronian rocks extending south-west from Concord and piercing the Mont Alban formation.

The existence of many minor faults is rendered probable, and it is proved that the diorite area of Salem, Swampscot and Marblehead has been thrown down thonsands of feet by a great fault which brought up the Norian rocks of Salem.

The Mont Alban formation is treated in a similar manner, but with less detail. The rocks of this age are shown to form, like those of the Huronian period, a complete chemical and lithological series, a rounded cycle of sedimentation.

Particular attention is given to the distribution and stratigraphical relations of the rocks of the Nashua and Merrimac valleys; and general sections across these valleys are given which show that the peculiar relations of the rocks are due to faults never before noticed.

The Mont Alban rocks are found, in their general distribution, to lie concentrically about the Huronian as the Huronian do about the Norian; and it is pointed out that these formations sustain precisely the same inter-relations in Maine, New Brunswick and Nova Scotia that they do in Massachusetts.

In this manner is established the existence of the great Eozoic Anticlinal, the erosion of which produced the gulf of Maine. The occurrence of Primordial and later sediments at various points in the Gulf of Maine, is appealed to as evidence that the erosion of this Anticlinal was completed before the beginning of Paleozoic time. Preceding the systematic account of the Palezoic rocks, two general sections are introduced showing the probable form of the valleys in which they were deposited.

The slates in the vicinity of Boston are chiefly referred to the Acadian period, while the great mass of the conglomerates is regarded as synchronous with the Carboniferous conglomerates of Bristol County and Rhode Island, which they closely resemble.

The conglomerates and sandstones forming the Norfolk county belt are referred, on stratigraphical grounds, to the Devonian Age.

The paper is concluded by an account of the disturbance closing Paleozoic time, wherein is traced the origin of many of the more prominent geological and topographical features of this region.

DEPARTMENT OF PHYSICS.

On the Mean Specific Gravity of the Earth. Abstract by the author, J. B. Henck, Jr.

1. General principle of all methods of finding the mean specific gravity of the earth.
2. First hint of an actual experiment by Sir Isaac Newton.
3. First actual attempt to determine the deviation of the plumb-line by the attraction of a mountain, as suggested by Newton, made by Bougner and others in 1738.
4. Maskelyne's experiments in 1774, Hutton's calculation of the results, and subsequent lithological survey of the ground by Playfair, with remarks on the use of the terms "quantity of matter" and "density."
5. Experiments by Col. James in 1856.
6. Experiments by Airy in 1826, 1828, and 1856.
7. Experiments by Pierce in 1874.
8. A second class of experiments, to be performed in the laboratory.
9. First experiments of this class, by Cavendish in 1797–98.
10. Experiments by Reich in 1837.
11. Experiments by Baily in the same and following years.
12. Second series of experiments by Reich in 1852.
13. Experiments by Cornu in 1873–74.
14. My own attempted experiments the past season.
15. Recapitulation of results.
16. References.

There are several sketches in the text, and a photograph of my own apparatus.

The Atomic Theory as Applied to Gases; with Some Experiments on the Viscosity of Air. Abstract by the author, Silas W. Holman.

This thesis is a result of a study of the "Atomic Theory" of the constitution of matter, especially in its application to the explanation of the phenomena of gases. A review of the theory, from its rise in the speculations of Democritus and others more than five centuries before the Christian era, to the most recent development in its application to the phenomena of gases by Clausius, Maxwell and many more, has been outlined in the first portion of the paper. The methods of application of the hypothesis of a gas made up of rapidly moving particles to the explanation of the relation between the pressure, temperature and density of a gas is next considered. This leads to a comparison of the results obtained by different investigators from the time of Boyle (1650) to the present. Such a comparison shows the uncertainty which still remains as to the nature of the derivation of gases from the law of Mariotte, and the desirability of a more thorough discussion of all the results yet obtained, as well as the need of more accurate observations at high pressures.

Another class of the phenomena exhibited by gases, namely, those due to their viscosity or internal friction, is one quite well adapted to test the conformity of theoretical deductions with the results of experiment. From the hypothesis of perfectly elastic spherical molecules (or their equivalents) acting upon each other by impact after moving over a rectilinear path, Maxwell has deduced the law that the viscosity of a gas is independent of the pressure upon it and increases proportionately to the 0.5 power of the absolute temperature. The experiments of Meyer, Maxwell, Puluj and von Obermayer on dry air have given, instead of 0.5, values of 0.75, 1.0, 0.66 and 0.75 respectively. These various results are discussed by a special application of the graphical method which shows a great discordance in the case especially of Meyer's extensive investi-

gations. These give in fact almost all values of the power from a negative one to +2.3, which shows that they entirely fail, even when their best values are selected, to establish any law for this variation. Maxwell's published results seem insufficient. Those of Puluj are more concordant. Only the conclusions of von Obermayer as published in a short notice have yet been attainable.

The apparatus which I have used in my experiments in the Physical Laboratory is dependent upon the law of Poiseuille as applied to the transpiration of gases through capillary tubes. This law is based upon the assumption that the viscosity of a gas is independent of the pressure upon it; a law which I consider as verified for variations not exceeding two or three atmospheres by the experiments of Graham, Meyer, and Maxwell. In this apparatus the same volume of gas is transpired successively through two capillaries of glass into a receiver continuously exhausted by means of a Richards' aspirator. The pressure of the gas at the entrance and exit of each tube is measured by means of two mercury gauges and a barometer. The capillaries may be at the same or at different temperatures. From the reading of the gauges when both are at the same temperature the constants of the apparatus may be determined, which must undergo a slight correction for variations of temperature since they depend on the dimensions of the capillaries. When the tubes are at different temperatures, the effect shows itself in the guage readings. From these and the previously determined constants, the effect of the known variation of temperature upon the viscosity is determined. The errors of measurements of volumes of air are thus eliminated, and the accuracy of the results depends only upon the measurements of temperatures and columns of mercury. As a mean of nine measurements I get the power 0.770, the extremes being 0.738 and 0.782. The greatest variation obtained with the apparatus was in the value 0.881 which was one of two observations rejected at the time of making. This form of apparatus does not furnish absolute values of the coefficient of viscosity, but may

be readily extended to accomplish this by measuring the volume of gas transpired in a certain time. The superior concordance of these preliminary results warrants the expectation of absolute values surpassing in accuracy those of previous investigations.

The deviation of all experimental data upon this law from the theoretical value of the 0.5 power of the temperature indicates, probably, a false hypothesis with regard to the mode of action of the molecules at impact. Maxwell has rëinvestigated this subject upon the hypothesis of a repulsive force between the particles varying inversely as the fifth power of the distance, which makes the viscosity proportional to the first power of the absolute temperature. This is probably not the law however, and it would seem that it would be necessary to establish the experimental law with certainty before giving ourselves to any theoretical deductions from it.

New Experiments in Sound. Abstract by the author, William W. Jacques.

The experiments consisted of three series. The first was made for the purpose of testing the law of inverse squares; the second to show that the principles of Fresnel and Huyghens, announced for the ether waves, could be applied to waves of sound; and the third, for the purpose of measuring the velocity of sounds of considerable intensity.

First Series — There is every dynamical reason for believing that the intensities of light, heat and sound diminish as the reciprocals of the squares of the distances from their origins. That this is true of light and heat has been demonstrated experimentally. The case of sound, however, has hitherto received no experimental demonstration. The following experiments furnish us with a proof of this law for the case of sound.

If two resonators be placed equally distant from an organ pipe, and connected by tubes with two prongs of a forked tube in such a way that the waves from the two resonators shall

arrive at the fork in opposite phase, they will neutralize each other, and if the stem of the fork be connected with the ear no sound will be heard.

If, for one of the resonators, we substitute a pair, we may, by moving the single resonator nearer to the organ pipes and properly changing the length of its tube produce the same complete interference. If the law of inverse squares holds good, the distances of the single resonator and the pair from the pipe should be as one to the square root of two.

The observed and calculated results agree almost exactly, so that we are now warranted in assuming the law for sound on as valid experimental grounds as for light and heat.

Second Series — There seems to be no *à priori* reason why the principles of Fresnel and Huyghens should not be applied to our atmosphere. The following experiments on the diffraction of sound show that they may be so applied. It is well known that when light, diverging from a centre, passes by a sharp edge, an interference is produced, so that, if a screen be placed just behind the edge, we shall see upon it alternate light and dark bands. The experiments which we have made in sound are analogous to these. In the path of rays of sound diverging from an organ pipe, an edge, consisting merely of a wide board, was interposed. In the rear of this edge alternate bands of maximum and minimum intensity of sound were observed, corresponding, in their positions, to the theoretical bands calculated by formulæ essentially similar to those used in the case of light.

From the data furnished by these experiments, we may calculate the length of a sound wave, the velocity of sound, and, in short, all of the quantities dependent upon the velocity of sound, as well as acoustic quantities analagous to the optical quantities deduced from the diffraction of light.

Third Series — Many eminent mathematicians and physicists have raised questions as to whether the velocity of sound is not affected by its intensity and pitch, by barometric pressure, hygrometric state and by other supposed causes. The follow-

ing experiments, which form one of several series being made for the settlement of these questions, have for their object the measurement of the velocity of sound near to the mouth of the cannon. If the velocity varies with intensity, these results should be larger than those obtained by other methods.

The method consists of an automatic measurement of the velocity between the members of a series of membranes, placed at different distances from the source of sound, by causing the sound, as it passes each membrane, to register its passage, by means of suitable electric connections, on a chronograph.

By the kindness of Colonel Laidley, commander of Watertown Arsenal, the experiments were carried on at that place.

The gun used was a six-pounder. From the mouth of the gun a series of three membranes was set up at intervals of thirty feet. These membranes were made of thin rubber stretched over a hoop nine inches in diameter. To the centre of the membrane was attached a polished brass shelf, upon which rested a polished steel spring. The shelf was connected with one wire, and the steel with the other running to the chronograph. When the spring rests upon the shelf it completes a circuit, which is the primary coil of an inductorium. The passage of the sound wave by a membrane breaks this circuit, and so causes a spark to pass between the terminals of the the secondary coil of the inductorium. The chronograph used was a Schultz, which consists essentially of a rapidly revolving polished silver cylinder, upon the lampblacked surface of which a tuning fork is allowed to draw its curve, and so to furnish a scale of times. One terminal of the inductorium is led to near the cylinder through a glass tube; the cylinder itself forms the other terminal. The breaking of the primary circuit at the membranes, then, causes a spark to pass from the wire to the cylinder, which is registered by a dot in the lampblack. An arrangement was attached to each of the membranes, by means of which the current, after being broken at it, could be sent through the next one before the sound wave arrived at it. The experiments which have been made show that the velocity of

sound in the vicinity of a gun is greater than at a distance by several feet. This is in accordance with theory. The method will, probably, when perfected, furnish the most accurate results of the velocity of sound yet obtained.

There is also a chapter describing some experiments made in a section of the new Sudbury River Conduit to test the effect of a very great variation of pitch upon the velocity of sound; and a final chapter describing a method to be used in the study of the effects of barometric pressure and hygrometric state of the atmosphere on the velocity of sound.

DEPARTMENT OF SCIENCE AND LITERATURE,

Australian Colonies of Great Britain. Abstract by the author, Chas. A. Sawyer.

Under the above title are included the following: New South Wales, Victoria, Tasmania, New Zealand, Queensland, South Australia, Western Australia, Fiji Islands.

Occupying, as they do, a position second only in importance to that of India, the colonies of Great Britain in Australasia demand something more than a merely general treatment as a group. In this thesis therefore I have entered somewhat into the details of each colony in its relation to the others of the group, paying also particular attention to their relations, commercial and political, with the mother country, and not only as a group but individually. In order to do this to better advantage and to systematize the treatment of the subject as much as possible, I have divided it into two parts as follows. In the first part I have briefly sketched the general and more important points in connection with the early discovery and history of Australia, this being common to all the colonies of the group, New Zealand alone excepted; I have also indicated their present relative positions as regards commerce, industry, and general prosperity, and verified my statements as far as possible by means of statistics and quotations from books and papers of au-

thentic publication. This part of the subject is treated under the following heads: History and Discovery; Climate and Physical Features; the Natives; Government, including the colonial system of land tenures; Trade, Commerce and Industry. In the preparation of the pages devoted to this first part the following authorities were consulted:

"Australia and New Zealand," (3 Vols.), by A. Trollope.

"Australia," by Wm. Westgarth.

"Discovery and Exploration of Australia," (2 Vols.), by Rev. J. E. T. Woods.

"Life and Growth of Language," by Whitney.

"Queensland, Australia," by Rev. J. D. Lang.

"Colonial Constitutions," by Sir Edwd. Creasy.

Stateman's Year Book (1876), by Martin.

Edinburgh Review (1865).

In the second part I have taken up the colonies separately in the order of their commercial importance, and entered into a more detailed account of each and with special reference to its commercial relations with others of the group and Great Britain.

New South Wales, though at present occupying a second place in the list as thus arranged, is the oldest and parent colony of all those that have grown up about her, and for this reason therefore I have given her the preference to Victoria in the order of their treatment. Comparisons of the colonies have been made, under the different heads into which the treatment of each is divided, in order better to show the kinds of industry, agricultural, pastoral or manufacturing, characteristic of it, and to which the natural resources of each seem best adapted. The divisions under each colony are as follows:

Area; Discovery and History; Climate; Geology and Mining; Natural History; Laws and Government; Population; Education and Religion; Revenue and Expenditure; Trade and Commerce; General Items. The same scheme is not followed in the treatment of each colony, however, though varying but slightly throughout the list, one topic being necessarily in-

cluded perhaps in another and not requiring a separate discussion or admitting of it in some cases.

Statistics have been given the preference to more interesting facts in connection with the history and present condition of the colonies, of which many have been reluctantly passed over and omitted. More space has been devoted to Victoria as the most important, and less space to Western Australia as the least important, of the colonies of the group.

The authorities referred to in this division of the subject include those already mentioned together with the following: Accounts and Papers of the Colonial Government, 1852–3; Greater Britain, by C. W. Dilke; What we saw in Australia (1875); The colony of Victoria, by Wm. Westgarth; Victoria and Tasmania by Trollope; Dublin Univ. Magazine, Jan. 1876; Journal of the Statistical Society, Dec. 1875; Goldfields of Victoria, by R. Brough Smith; Victoria and the Australian Gold mines, by Westgarth.

DEPARTMENT OF PHILOSOPHY.

Concerning Kant's Transcendental Æsthetic. Abstract by the author, D. W. Phipps.

I.

EXPOSITION OF KANT'S IDEA OF A CRITIQUE OF THE PURE REASON.

1. Mutually independent Mind and Thing assumed.

2. The assumed hypothesis (to be proved) that the qualities of the object pertain only to the Mind.

3. In consequence of the assumed duality of Mind and Thing; together with the apparent element of universality in experience, the theory arises that

(*a*). There are two sources of knowledge, viz., Sense and Understanding.

(*b*). And hence the problen of the Critique: How are synthetical judgments possible *a priori*?

4. The Sense-cognition, as distinguished from the cognition of the Understanding, has an element which is contributed by the spontaneity of the Mind; hence,

5. The necessity of a Transcendental Æsthetic; which is a critique of the spontaneity in the sense-object, as distinguished from the spontaneity of the Understanding; the critique of the latter being named Transcendental Logic.

6. What we shall expect Kant to prove in the Æsthetic, in view of the foregoing notion of its purpose.

II.

REMARKS CONCERNING THE PLAN OF THE ÆSTHETIC; AND NOTICE OF SOME OF ITS DEFECTS.

III.

AN ATTEMPT TO RESTATE THE ÆSTHETIC SO AS TO AVOID SOME OF THE NOTICED DEFECTS.

1. *Definitions:* Sense; Intuitions: pure, empirical, external and internal; Phenomenon; Sensation, Space and Time; Matter, Form.

2. The Æsthetic a critique of Space and Time.

(*a*). Space and Time to be explained Metaphysically and Transcendentally.

3. *Metaphysical Exposition:*

(*a*). What a Metaphysical exposition is.

(*b*). Space and Time are not general concepts.

(*c*). They are not concepts of any sort; and as an intuition can be given by a single object only, so Space and Time are like intuitions, for they are each only one.

(*d*). Space and Time give rise to synthetical propositions *a priori*; but a conception contains only a unity of certain marks or characteristics, which may be discovered by analysis, and does not contain anything beyond those marks; hence a conception cannot give synthetical propositions *a priori*; hence Space and Time are not conceptions; hence they must be intuitions.

4. *Transcendental Exposition:*

(*a*). What a transcendental exposition is.

(*b*). What "transcendental" means.

(*c*). An object cannot be cognized as extended and enduring unless there be the representation *a priori* of Space and Time, in which the object may extend or endure.

5. The exposition of Space as a representation *a priori*, makes possible the conception of mathematics as a synthetical science *a priori*. And motion, the change of place of an extended object in Time, can be understood, and explained *a priori*, only on the ground of the representation *a priori* of Space and Time.

6. *Conclusions:*

(*a*). Space and Time are subjective, only, but universal.

(*b*). Sensation is subjective, only, but singular.

7. *Elucidation:*

(*a*). Change is real for us.

(*b*). Space and Time are only elements of a Transcendental Æsthetic.

8. The bearing of the completed Æsthetic upon the solution of the main question: How are synthetical judgments possible *a priori*?

IV.

QUERIES.

1. How did Kant discover that the Sense-object was *occasioned* by the thing-in-itself?

2. Has he proved that Space and Time are *a priori;* that is, universal and necessary, but independent of sensation?

3. Has he proved that Space and Time are intuitions?

4. If Space and Time are independent knowledge of *one* sort, and Sensation is independent knowledge of *another* sort, how can the two sorts be united?

5. Is the so-called *a priori* from the *human* reason or from *Reason*? that is, do we not know the Absolute?

6. Has Kant's theory of cognition provided for Transcendental reflection?

Historical and Logical Relations between Fichte and Kant. Abstract by the author, R. C. Ware.

Fichte's adoption of the philosophic standpoint of the absolute validity of reason, through his researches in theology. His adoption of a fatalistic determinism. His subsequent conviction of the freedom of the will by Kant's new theory that the nature of liberty is subjective. Fitche's hearty acceptance of Kant's doctrine. Fitche's visit to Kant. The "Critique of all Revelation," an application of the "Critical" Principle. Development of Fichtianism by reflection on the contradiction of Kant. Development of the theory of intellectual intuition by reflection on the implications of the "Transcendental Logic." Derivation of the Ego as ground of the universe, and of the one fundamental principle of thought (the Principle of Identity), from Kant's "Synthetical Unity of Apperception." Development of Fichte's theory that will is a necessary part of real thought, out of the adoption of Kant's practical philosophy. The real character of the revolution wrought by Kant in philosophy.

THE RUSSIAN SYSTEM OF SHOP WORK INSTRUCTION.

To the Corporation of the Mass. Institute of Technology:

GENTLEMEN: — It must be admitted that technological education is still in the experimental state. The methods in use, even in our primary schools, do not pass unquestioned, and upon the best methods of teaching the ancient languages, and the pure mathematics, subjects which have constituted the main elements in all high and generous culture for ages, the most learned doctors disagree. We could hardly expect, then, that the best methods of teaching the modern sciences should already have been found; and particularly the best way of working them out practically in the industrial arts. Ten years ago, when the courses in this Institute began, some valuable experience in teaching science had been gained. It had been found that simple text-book instruction in Chemistry, unaccompanied by corresponding laboratory work by the pupil, was comparatively useless; that a small professional laboratory, while good for an advanced specialist, was no place for a beginner; and, in short, it was too expensive to teach each pupil singly. Hence there had grown up, as a necessity, large and well arranged laboratories, especially adapted to the instruction of pupils in as large classes or sections as one or more teachers could instruct well at the same time. This step of teaching laboratory work to large classes of pupils, and all in about the same state of progress, was found to be most economical for both parties, and the only system by which this element of instruction could be maintained with a large number of pupils. It has also been found by experience that general chemistry, quantitative and qualitative analysis, and the various departments of

applied chemistry, can best be taught in laboratories adapted to each. Such are the steps which have been taught us by experience in a single department. But unfortunately, in hardly another department have we the same experience, and an equally well defined and systematic method of instruction. In architecture, in laboratory instruction in physics as a part of the required course of each candidate for a degree, in the mining and metallurgical laboratories for the working of ores in quantities, and in the laboratory for teaching the nature and use of steam, this Institute has the honor of having led the way. But in these cases each year's experience serves to suggest improvements in details, which add materially to the amount and quality of the work done.

While we have been gaining experience in these directions, other technical schools have also been working out, more or less fully, other phases of the same great educational problem upon which we are all engaged; each doing its work under such limitations and conditions, and in such main directions, as its location and other controlling circumstances have dictated. Each, therefore, owing to a great extent to these varying circumstances and conditions, has its lesson to teach to all the others; and it was with the expectation that the opportunity of learning some of these lessons would offer, that our Professors and Students made their recent visit to the International Centennial Exhibition at Philadelphia.

The Act of Congress of 1862, giving lands to the States for educational purposes, while not excluding other subjects, laid particular stress upon the two great industries upon which the well-being of any great community must always mainly depend, agriculture and the mechanic arts. While all the sciences having a direct application to these arts should be taught, there can be no doubt that it was also the intention that the arts themselves should be taught in the most practical and fundamental way; and accordingly, we find farms in several of the States, used in one or two cases, simply as experimental stations, but in most cases conducted as model farms, and depending to a considerable extent upon the labor of the student, which is regarded as instruction, and is made a required part of the curriculum of the course in agriculture.

In like manner many of these schools have already established shops for the instruction of their students in the mechanic arts.

As this Institute was selected by the State to represent the mechanic arts, for which we receive one-third of the income derived from the national grant, we have watched the experiments in this department, which the various schools have been making with the deepest interest; believing, that the time would come, when the best solution would be reached, and trusting that when it was reached we should be in a condition to take advantage of the experience. In the meantime the steam laboratory is all we have been able to furnish of a practical character to our students in mechanical engineering, beyond what could be gained by a good locality for manufacturing, and the particular kindness of the directors.

We went to Philadelphia, therefore, earnestly seeking for light in this as well as in all other directions, and this special report is now made to ask your attention to a fundamental, and, as I think, complete solution of this most important problem of practical mechanism for engineers. The question is simply this — Can a system of shop-work instruction be devised of sufficient range and quality, which will not consume more time than ought to be spared from the indispensable studies?

This question has been answered triumphantly in the affirmative, and the answer comes from Russia. It gives me the greatest pleasure to call your attention to the exhibit made by the Imperial Technical Schools of St. Petersburg and Moscow, consisting entirely of collections of tools, and samples of shop-work by students, illustrating the system which has made these magnificent results possible.

In all constructions a certain limited number of typical forms are found, these forms being more or less modified, to adapt them to special constructions. These forms will also fall into groups each to be worked out in a certain way and with special tools. If, then, the student can be taught to work out these forms, each in the best way, and with the tools best adapted to the work, he will be far advanced in the skill which will make him available and useful in construction. The ideas involved in the system are, first, to entirely separate the *instruction* shops from the *construction*

shops; second, to do each kind of work in its own shop; third, to equip each shop with as many places and sets of tools, and thus accommodate as many pupils, as a teacher can instruct at the same time; and fourth, to graduate the samples to be made in each shop according to some scale, that of difficulty being probably the best in practice. In short, in these preliminary instruction shops, the *arts*, which find their applications in construction, are systematically taught.

It will be seen, then, that the problem thus far is simply one of systematic instruction, given by an expert in each shop, and having the same end in view as instruction in any other subject or department. The aim is to give sufficient skill in each specialty in the shortest possible time, and to give the instruction to as many at the same time as the teacher can well instruct, thus securing the greatest economy of time, and therefore money, to both teacher and pupil. After the student has finished his course in the several instruction shops, he may then be transferred to a construction shop, which may still be used simply for instruction as in the St. Petersburg school, no orders being taken, and all constructions being made simply to give variety to the instruction; the machines and tools made being sold at the end of the year if wanted.

Or he may be transferred to a construction shop, which takes orders and depends largely upon the work of the pupils, as at the Moscow school, the construction shops being in each case owned and controlled by the school.

With this preliminary exposition, I propose now to ask your attention to details, mainly in connection with the statements which these schools make in explanation of their exhibits at Philadelphia.

And first, the statement of the St. Petersburg school:

"The Practical Technological Institute of St. Petersburg is one of the highest technical schools now existing in Russia, and has capacity for five hundred students. It is divided into two departments; Mechanical and Chemical.

The Mechanical Department prepares technical men for the management of mechanical work-hops, and of the rolling stock on railroads. Owing to this the Mechanical Department is divided

into two special sections; one of them graduates engineers for the workshops, and the other for the railroads.

Before entering the Institute as student the young man must be graduated in one of the middle schools (gymnasiums), and must undergo a competitive examination.

The whole course of instruction in each department of the Institute is arranged for five years, and is divided into five yearly courses.

In the Mechanical Department the course of instruction includes: Mathematical analysis, natural philosophy, theoretical and practical mechanics, mechanical technology, the art of construction, and the art of mechanical drawing. Besides this, a part of the time is employed by the students in manual labor in various workshops and mills belonging to the Institute.

During the full five years of the course of studies, six hundred and forty-eight hours are devoted to the manual labor in workshops. There the students, under the management of experienced masters, begin to exercise in the most simple works, gradually passing to more complicated, and at last finishing with construction and joining of all the parts of an engine.

The collection of practical works exhibited in the Machinery Hall by the Institute is composed of articles manufactured by the students during the year 1875, and represents the systematical course of practical studies adopted by the Institute.

The system introduced with this purpose is as follows: The practical studies are divided into three courses; for the first course each student is induced to work with a chisel and file upon the cast-iron, performing six consecutive tasks exhibited under the No. I. of the collection.

For the second course the students begin by working upon wrought-iron, fulfilling nineteen consecutive tasks represented under the No. II. of the collections. Thereafter they are removed to the fitting shops, where they are obliged to perform fifteen tasks, exhibited under the No. III. of the collection, occupying themselves with turning, cutting screw-threads and soldering.

The last course is intended for the construction and joining of different engines. The samples of machine tools built by the students of this course are exhibited under the No. IV. of the collection."

I am indebted to Dr. August Peters, Mechanical Engineer, and Director of the shops of this school, for the following details: The filer's shop, No. I, has about sixty places, each fitted with a vise, and the tools necessary to do the work of the course. The forging shop, No. II, is fitted with ten places, and the turning shop,

No. III, with sixteen places, the students working in these shops in alternating sections. The lathes are all run by the foot, and the only power used in any of these instruction shops is for the blast in the forging shop, which each student takes from the main pipe. Even here power could easily be dispensed with by attaching a hand blast to each forge. The shop work, which, it will be noticed, takes but six hundred and forty-eight hours for the four courses, is obligatory, and graduates are able to construct their own designs with their own hands.

The quality and variety of the work exhibited, and all done by the students during the year 1875, furnish the very highest evidence of the value and entire success of the system.

And second, I beg you to particularly notice the able and instructive presentation of this important subject by Victor Della-Voss, Director of the Imperial Technical School of Moscow, together with a brief preliminary statement of the general features of the school. I am indebted to Professors Aeschlimann and Petroff, the gentlemen in charge of this exhibit, for polite attentions.

"The Imperial Technical School of Moscow is a high class Special School, principally intended for the education of Mechanical Constructers, Mechanical Engineers and Technical Engineers.

The School consists of two divisions, general and special, each of which has a course of three years. The special division is divided into three branches: Mechanical Construction, Mechanical Engineering and Technological Engineering.

The three years' course of the general division embraces the following subjects: Religion, Free Hand and Linear Drawing, Descriptive Geometry, General Physics, Zoology, Botany, Mineralogy, Chemistry, Geodesy, Analytical Geometry, Higher Algebra, Differential and Integral Calculus, General Mechanics, Drawing of Machine-parts, the French and German Languages, *i. e.*, all Scientific subjects, the previous knowledge of which is required from the pupils of all the three following branches.

In the special department, the three years' course of the three branches contains the following subjects: Organic and Analytical Chemistry, Metallurgy, Practical Physics, Mechanical and Chemical Technology, Technics of Wood and Metals, Analytical Mechanics, Construction of Machines, Practical Mechanics, Railway Construction, Engineering and Constructive Art, Projecting and Estimating of Machines, Works and Mills, Industrial Statistics, and Book-keeping.

Every one of the appointed sciences is taught fully, or in a condensed form, according as it is considered a fundamental or collateral subject of the given branch. The students of all the classes are occupied during a stated time in practical work in the laboratories and mechanical workshops.

The School has also a preparatory division, of three classes, with the same curriculum as the higher classes of commercial schools, and is intended for such pupils as, by any reason whatever, have not been enabled to pass through the full course of the commercial or of the classical schools.

Admission into the School as boarder or day scholar is obtained by competitive examination, in accordance with the ordained programme.

Pupils who have passed through the full school course of the Gymnasiums may be admitted without further examination to the lectures of the second general class of the School, but pupils of the last class of the Gymnasiums, who have not passed their final examination, are admitted only to the first general class of the School.

The pupils wear the appointed half-military uniform.

Pupils who have obtained in the school the appointed grades, receive acknowledged rights in the service of the government.

The School is maintained by funds from the following sources: percentage on funded capital,[1] fees of private boarders and foreign hearers, and profits received from the Mechanical Works.

The annual receipts of the School amount to 160,000 dollars.
" " expenses " " " " 140,000 "

The Technical School is under the immediate patronage of *Their Imperial Majesties.*

Auxiliaries to Instruction. The School possesses a special library, containing more than six thousand volumes of works on specialties, a cabinet of physics, two chemical laboratories, a cabinet of mechanical models, a cabinet of natural history, extensive mechanical works with separate smithy and foundry, and also school work-shops.

Almost the whole of the collections exhibited by the School at the exhibition at Philadelphia, are immediately connected with the school workshops, and we shall therefore endeavor to give a few details concerning the latter.

No one will deny that a close acquaintance with hand labor, and, in general, practical experience in mechanical works, are matters of the utmost importance to every engineer.[2] The drawings of an engineer thus trained will always be distinguished by solidity and that practical judgment, which is the result not only of the study of scientific truths, but also of the acquirement of a

[1] The School capital amounts to about 2,030,000 dollars.
[2] We speak here of Mechanical Engineers and Constructers.

certain familiarity in their application to practice. That the knowledge of hand labor is of extreme importance to a young man devoting himself to technical activity, and that it is considered an absolute necessity to him, we are convinced by the circumstance that the greater number of the polytechnical schools of western Europe demand from the students who enter them either a previous stay, of a certain duration, at some works of industry, or issue to them a diploma, attesting their accomplishment of the course, after they are in position to show that they have been occupied practically for a definite period at some such works on their leaving the school.

If we contemplate the matter itself more profoundly, and acquaint ourselves more closely with the circumstances of the practician at private works and mills, we must, disregarding exceptional cases, since it is not those which form the rule, arrive at the sad conclusion that a young man, desiring to acquire practical experience in a short time, and without the aid of an experienced guide, loses, at private works, nine-tenths of his whole time entirely unprofitably. As we are at present addressing persons well acquainted with this matter, we do not consider it necessary to bring forward arguments in support of our statement. The practical information, acquired in works by a young man before entering a polytechnical school, is very inconsiderable, and therefore does not possess the desired significance.

Such information is, on account of its defectiveness, of little assistance in promoting the study at school of Practical Mechanics, the construction of machines or the drawing up of plans and estimates for mills and works.

A young man on leaving a polytechnical school should endeavor to carry on his practical education; should fix upon some mill or works in which, being, in the majority of cases, of course, left to his own initiative, he may find place and opportunity for his further self-education.

At this moment, so critical in the career of the youthful engineer, the insufficiency of material resources is the cause that the majority take service, at a very low rate of remuneration, as draughtsmen in the drawing office of mechanical works, or in the drawing offices of railway companies; others more fortunate enter works in the quality of artizans; but even they are hardly to be envied, simply from the fact that in the majority of cases the specialty of the first works, which they happen to enter, becomes their own specialty through life. An experienced observer will find no difficulty in perceiving all the inconveniences to a technical education, which arise as the result of such an order of things. Let us explain this by examples. A young man, having received thorough scientific preparation in a polytechnical school, has entered as artizan practician some extensive joiner works, and in a year or two begins to serve in the capacity of a workman, receiv-

ing pay from the works. If, from any circumstance whatever, he becomes deprived of his place, he finds it necessary to seek another in a similar joiner works, or else to enter again as practician in another specialty, for instance, a locomotive, boiler or other works. The material resources of young men, preclude, in the majority of cases, the possibility of their deciding on the latter alternative.

If the observant Directors of Polytechnical Schools should take upon themselves the work of following the industrial career of the contingent of their pupils, who on leaving school enter a drawing office, they would easily perceive that those young people experience extreme difficulty when they are once engaged there in leaving such an office, and in the majority of cases remain draughtsmen all their lives. In such offices a young man acquires but very inconsiderable technical information, neither can they in any way serve him as practical schools for his further self-instruction. And we must here observe, also, that the more extensive the works, and consequently the drawing office attached, the fewer are the advantages offered to the young practician, since he has to do with an institution in which division of labor, forming an essential principle, will not admit of his becoming speedily acquainted with the general progress of work. We cannot but add that this principle having become latterly extensively applied in all large works and mills, though on the one hand bringing considerable material advantages to the proprietors, has, on the other, greatly influenced the depreciation of the level of technical knowledge among the workmen, by confining that knowledge within the limits of narrow specialization.

The technical education afforded to young men in almost all the Polytechnical Schools of Europe leaves, theoretically speaking, little to desire, but is exceedingly imperfect practically, and demands the particular attention of those persons who are entrusted with such instruction.

The peculiar circumstances, by which the young people who have finished the course of the Polytechnicums find themselves surrounded, do not admit before their entering upon an active life, of the acquirement of even a superficial general practical education, but place them in the necessity of devoting all their activity from the first day of their leaving school, and often their whole life, to a narrow specialty. The attention of the Directors of Polytechnical Schools has often been drawn to this, and attempts have frequently been made to familiarize young people at school with the practical work of mechanics, but all these endeavors have proved to be unattended with success from the following reasons:

1. The school workshops for the practical occupation of the students were constructed on a very miniature and inconsiderable scale.
2. The consequent want of room in these workshops did not admit of all the students being occupied at the same time, and therefore their attendance was not obligatory, while the majority of the professors and masters expressed their disapprobation of such employment.

3. There existed no systematical method of practical instruction in the workshops similar to that which had been applied to the practical teaching in the chemical laboratories.
4. The material resources assigned for the maintenance of the school workshops were very inadequate.
5. The time allowed for the full course of study in the Polytechnical Schools was insufficient to admit of the combination, in that course, of theoretical with practical instruction in technology.

Though there have appeared some literary articles against the introduction of practical instruction with workshops into the higher technical schools, yet it is our subjective opinion that those articles appeared only in defence of the existing order of things, and to justify a certain lukewarmness in introducing advantageous measures, but no demonstration of the results of trial were afforded among the arguments against such a mode of instruction, for the simple reason that excepting feeble attempts, no serious experiments have been made. Even those attempts themselves were made without any particular energy and due observativeness.

We do not here take into calculation some of the at present existing technical schools of France, which possess sufficiently extensive school workshops,[1] because those schools belong rather to the lower class technical institutions, and do not give to the world mechanical engineers and constructers, but only foremen (contremaîtres).

The slight acquaintance of learned technologists with practical work in mechanical workshops, entails the unfortunate consequence that in the greater number of even very extensive works the practical part remains in the hands of routined artizans who have received no scientific instruction, but who have attained their exceptional position by accustoming themselves during the course of many years to the most obsolete methods of practice in the mechanical art.

Seldom do the rays of science penetrate that unenlightened sphere of labor, and, meanwhile, it has so long demanded scientific guidance.

The Imperial Technical School of Moscow, the course of which, from the theoretical subjects taught therein, equals the course of many of the Polytechnical Schools of Western Europe, combines theoretical with practical education, and consequently is enabled to present real proofs of the possibility and advantageousness of such combination, since the trial of this combination has been made on an extensive scale, and during a considerable length of time.

Every thing that we have exhibited at the international exhibition relates exclusively to this, in our opinion, important question, and was exhibited in the desire of sharing with specialists in the

[1] These are the schools of Chalons, Aix and Angers.

work of technical education in the New World, all those results which have been attained by the School in the independent investigation of this special question.

For the practical education of young men in the two branches,— mechanical engineers and mechanical constructers[1]— the school possesses large mechanical works with hired workmen, accepting and carrying out orders from private individuals, and on a commercial footing, for the construction of steam engines, working engines, pumps, transmissions, agricultural machines, etc.[2]

The works consist of the following shops: Joiners' shop, Engineers' shop, Erectors' shop, Painters' shop, a large Forge with steam hammer and fan blast, iron foundry with furnace for 3000 kilogr. of metal, and brass foundry; the works have also a drawing-office and counting-house attached to them.

A steam engine of thirty horse-power is used for the working of the place, while the foundry with fan blast and coal pulverizing-mill are worked by an engine of ten horse-power.

The works are under the management of the head mechanical engineer (vacant) and his assistant, Platonoff, mechanical engineer.

The drawing-office is in the charge of Petroff, mechanical engineer. All the mentioned persons have passed through the course of our school.

These works being within the walls of the institution itself, and managed by well-instructed technologists, would be of important assistance in the instruction of young people, even if the young people took no active part in the practical working of them.

But in order that the pupils may derive the greatest possible advantage from such auxiliaries, the school possesses, apart from the mechanical works, and intended solely for the use of the pupils, school workshops: joiners' shop with turning lathe, pattern shop, metal turning, fitters' shop, smithy and moulding shop.

Every one of these shops is under the management of a technologist — specialist,[3] or of a skilled workman, and their duty is to instruct the pupils in the rudiments of mechanical labor.

Every young man becomes acquainted, by fulfilling the obligatory programme, with all the work of mechanical art, namely: turning, fitting, carpentering and forging, in the school workshops, and only then is admitted to the mechanical works.

We shall endeavor to speak further, on the system of teaching the arts in the mechanical workshops of the school.

Up to the present time throughout the world, the workmen at industrial works and mills are usually self-taught. Any one who

[1] Young men studying the technological engineering branch are admitted to the laboratories instead of the mechanical workshops.

[2] These works execute private orders to the sum of from 35,000 to 46,000 dollars annually.

[3] The wood turners' shop is in charge of Mr. Adelmann, the smithy — Mr. Bouroff, carpenters'— Mr. Michaeloff, metal turners'— Mr. Markoff, moulders'— Mr. Koumenius, and the fitters' shop—Mr. Sovetkin, mechanical engineer.

has himself been employed at works, and is familiar with the daily life of the workman in the different countries, must have perceived that the acquirement of knowledge and skill in any trade is to him a process much similar to the following: a boy of thirteen or fourteen years of age having entered a mechanical works to learn his trade, is put during the first few years, to work of an entirely unproductive kind, and which has not the slightest relation to technics. He is made to carry water, sweep the workshop, crush emery, grind colors, etc. Only after the lapse of a few years, and probably, thanks to accidental circumstances, a chisel or a file is put into the hands of the youth, and he is set to perform the rudest and simplest kind of work.

Then, also, if he happen to have neither father nor brother among the workmen around him, he begins learning his trade without a guiding hand, and thus commences acquiring practical knowledge and skill in his trade by observing those about him in the workshop, and by his own thought and calculation, and impelled by the sole desire of attaining in as short a space of time as possible the position of a paid hand in the works. There can be no doubt that under such circumstance the acquirement of skill by the new generation of workmen takes place in an extremely irrational manner, and without any system; the amount, of knowledge obtained depends upon accident, and the time thus employed is of disproportionate length. Besides this, there is yet another inconvenience, namely, that of specializing labor to too fractional a degree. The young workman, placed accidentally either to a drilling or planing machine, or a self-acting lathe, endeavors to remain as long as possible at his machine, encountering, it will be understood, no objection on the part of the heads of the workshops, since such specialization of labor redounds to the advantage of the proprietors, owing to the abundance of hands.

This order of things has the deplorable result, that notwithstanding the long continued stay of the young workmen at mechanical works, and which is sometimes prolonged through the major part of the years of their manhood, well-taught and skilled fitters are almost everywhere rarely to be met with. This will be confirmed by all those constructers who demand skilled labor for the erection of models, and of the more or less delicately constructed instruments, machines and apparatus.

During the past few years endeavors have been continually made to open schools for the instruction of the workmen at all works of any considerable extent. The subjects taught in these schools are free hand and linear drawing, arithmetic, and many others, in the supposition that practical knowledge of works will be acquired in the works themselves.

From this it is impossible to conclude otherwise than that society, while taking measures to civilize the working classes, gives, at the same time, no attention whatever to the manner in which the

young workmen acquire practical experience in their trades at the works; no endeavors have been made in that respect, and, meanwhile, as is our subjective opinion, the question is worthy of particular attention.

The conclusion, however, forces itself upon us that this question can hardly be entered into until the young well-taught technologists, leaving Polytechnical Schools, shall themselves possess rational experience in practical hand labor. In order that their education as specialists shall be full and ample, such knowledge is indispensable in the highest degree, though until the present time, it has unfortunately presented a prominent deficiency in their instruction. Who will not admit that the knowledge of the manner of executing given work is a necessity to one who has to issue the project of such work?

Acting on the principle that mechanical engineers and mechanical constructers, whose future activity will be devoted preeminently to mechanical works, should have practical experience in the mechanical arts, the imperial Technical School has employed every necessary measure for the solution of this difficulty in the best possible manner.

In 1868 the School council considered it indispensable, in order to secure the systematical teaching of elementary practical work, as well as for the more eonvenient supervision of the pupils while practically employed, to separate entirely the school workshops from the mechanical works in which the orders from private individuals are executed, admitting pupils to the latter only when they have perfectly acquired the principles of practical labor.

By the separation alone of the school workshops from the mechanical works, the principal aim was, however, far from being attained; it was found necessary to work out such a method of teaching the elementary principles of mechanical art as, firstly, should demand the least possible length of time for their acquirement; secondly, should increase the facility of the supervision of the gradationary employment of the pupils; thirdly, should impart to the study itself of practical work the character of a sound, systematical acquirement of knowledge, and fourthly, and lastly, as should facilitate the demonstration of the progress of every pupil at every stated time. Everybody is well aware that the successful study of any art whatsoever, free hand or linear drawing, music, singing, painting, etc., is only attainable when the first attempts at any of them are strictly subject to the laws of gradation and successiveness, when every student adheres to a definite method or school, surmounting, little by little, and by certain degrees, the difficulties to be encountered.

All those arts, which we have just named, possess a method of study which has been well worked out and defined, because, since they have long constituted a part of the education of the well-instructed classes of people, they could not but become subject to

scientific analysis, could not but become the objects of investigation, with a view of defining those conditions which might render the study of them as easy and regulated as possible.

This, however, cannot relate to those arts which have been hitherto pre-eminently followed by the common and imperfectly educated class of workpeople, but a knowledge of which appears at the present moment, to be of importance to the educated technologist.

These arts are: wood-turning, carpentering, metal-turning, fitting and forging. From what we have already said, it will not be difficult to arrive at the reason of the absence of a strictly systematical method for the study of them, nor why the active working out of such a method, without the aid of enlightened minds, may long remain deferred.

Meanwhile the necessity of such a method, more particularly for technical educational establishments, admits not of the slightest doubt, and the filling-up of this want promises evident advantages, not only in the matter of scientific technical education, but also with regard to the practical instruction of the work people, and consequently, the perfection of mechanical hand labor itself, which, from the introduction of specially adapted machinery is, year by year, perceptibly deteriorating.

If we except the attempts made in France in the year 1867 by the celebrated and learned mechanical engineer, A. Cler, to form a collection of models for the practical study of the principal methods of forging and welding iron and steel, as well as the chief parts of joiners' work, and this, with a purely demonstrative aim— no one, as far as we are aware, has hitherto been actively engaged in the working out of this question in its application to the study of hand labor in workshops. To the Imperial Technical School belongs the initiative in the introduction of a systematical method of teaching the arts of turning, carpentering, fitting and forging.

To the knowledge and experience in these specialties of the gentlemen entrusted with the management of the school workshops, and to their warm sympathy in the matter of practical education, we are indebted for the drawing-up of the programme of systematical instruction in the mechanical arts, its introduction in the year 1868 into the workshops, and also for the preparation of the necessary auxiliaries to study. In the year 1870, at the exhibition of manufactures at St. Petersbourg, the school exhibited its methods of teaching mechanical arts, and from that time they have been introduced into all the technical schools of Russia.

The auxiliaries of education employed in teaching mechanical arts were exhibited at the international exhibition of Vienna, and now at Philadelphia, in order that specialists in these matters might become acquainted with them.

The auxiliaries of education appointed for the teaching of any mechanical work whatever, for example— fitters' work, are classed

in three categories; to the first of these belong the collections of instruments employed in fitters' work, with which the beginner must make himself perfectly familiar before entering upon work, and afterwards to use these instruments during the execution of the work itself.

To this category relate all those collections of models indispensable to the teacher of fitters' work, for the purpose of demonstration: the collection of instruments most in use for measuring, full size; the collection of instruments, full size, for drilling metals; the collection of instruments, full size, for finishing, from the smithy to the fitting shop inclusive.[1]

Models of files, increased to 24 times the ordinary size, for the purpose of demonstrating the surface of the incision; the collection of models of instruments employed in cutting screws and nuts, increased six times ordinary size, for the study of the direction of the angles of incision; the collection of models of drills, increased six times, for the practical study of the cutting angles; and lastly, the collection of instruments and apparatus for teaching the tracing of yet unworked metal articles. We consider it our duty to draw the attention of specialists to this last collection, for the organization of which we are indebted to our skilful instructor of fitters' work, Mr. Sovetkin, mechanical engineer.

To the second category belong the collections of models appointed for the systematical and gradationary study of hand labor in the fitters' art. These collections have the same signification with regard to the work of fitting as is allowed to scales and exercises in instruction in music. They are so ordered that the beginner may be enabled to overcome by certain gradations the difficulties which present themselves before him. It will be sufficient to glance at the adjoined detailed list of objects contained in these collections, and to examine attentively every object exhibited, to be convinced, that if the pupil, under the guidance of the teacher, carefully fulfils the study of all the numbers embraced in the collections, or rather the educational programme of the art of fitting, he must inevitably, and in the most rational manner, render himself familiar with all the known practical hand labor of this art.

Hence we arrive at the conviction, without any difficulty, that with such a system of teaching art, the supervision of the teacher over the pupils, and his observation of their progress, become exceedingly easy. He need only remark that every number of the programme is executed satisfactorily by the pupil, and putting the following one before him, give the requisite explanations for the succeeding work.

In such a case, the fact of a great number of pupils being occu-

[1] This beautiful and ample collection could not be sent to the Exhibition in consequence of the limited space allotted to us.

pied at the same time will present no great disadvantage, nor will it increase the arduousness of his duty to any considerable degree. And further, it will be a matter of impossibility that a pupil who has been working during a few years in the workshop, should fail to be able to use the drill, or to trace a part to be worked, though he handle satisfactorily the chisel or the file.

To the third category belongs the collection of such articles, or parts of machines, as in the execution of which all the practical hand labor of the fitter's art is successively repeated, having been acquired during the studies of the previous course.

What we have said in relation to the manner of study of the work of fitting, must be accepted also with regard to the other branches of labor, namely, wood-turning, carpentering, smithy and foundry work. We exceedingly regretted that the limited space allotted to us in the exhibition did not admit of our exhibiting all those collections of auxiliaries to instruction which the School has produced.

In conclusion, we consider it our duty to observe that eight years have already elapsed since the programmes of instruction in the mechanical arts were introduced into the workshops of the School, and they have been found to attain in the most brilliant manner the aim proposed in their introduction.

VICTOR DELLA-VOSS,

Director of the School, and Ex-Professor of Practical Mechanics at the Agricultural and Forest-Academy Petrofsky-Rasoumofsky.

Next I include a condensed catalogue of the exhibit of this School, showing the collections of tools pertaining to each kind of work, and the number of samples which each student must make in each shop. Attention is particularly called to the admirable series, N, O, P, of enlarged models for the practical study of the construction of cutting instruments, in the "School Fitting Shop."

SCHOOL WORKSHOPS.

I. WOOD TURNERY.

MASTER F. ADELMANN.

A. Collection of tools (about 150) for turning wood.
B. Part I. Samples (13) for the successive learning of turning in wood.
Part II. Casting-mould models of details and Machines (30).

II. MODEL JOINERY.

MASTER A. M. MICHAELOFF.

C. Collection of tools (34) for joinery.
D. Collections of tools (46) for joinery. Second series.

E. Samples (25) for the successive learning of joinery and pattern making.
F. Collection of models (25) of usual wood-joinings.
G. Collection of patterns (18) for iron castings.

III. FORGING.

MASTER S. BOUROFF.

H. Collection (60) of forging tools.
I. Samples (79) for the successive learning of blacksmith's manipulations.

IV. METAL-TURNERY.

MASTER A. M. MARKOFF.

J. Collection of tools (55) for turning metal.
K. Collection of tools (75) for turning metal. Second series.
L. Samples (38) for the successive learning of turning metal.
M. Samples (21) for the successive learning of turning metal. Second series.

V. SCHOOL FITTING SHOP.

MODELS FOR THE PRACTICAL STUDY OF THE CONSTRUCTION OF CUTTING INSTRUMENTS.

MASTER D. K. SOVETKIN, MECHANICAL ENGINEER.

Taking into consideration the importance of a knowledge of the proper construction of instruments, and the difficulty which has to be overcome in explaining to a whole mass of pupils the minutest details in connection with the direction and the angles of the incisive portions of instruments, we, already in the year 1872 endeavored to construct wooden models, representing instruments on a considerably increased scale. Part of these models was exhibited by us at the Polytechnical Exhibition of Moscow, in the year 1872.

Models of instruments on an increased scale present the advantage of rendering it possible for the student to see clearly all the minutest details of the construction of the instrument. The direction of the cutting edges, and also the shape and direction of the level surfaces which form the working part of an instrument, should be studied in the most detailed manner, and how is this possible when these portions of an instrument are hardly to be seen by the unaided sight. Let us take for an example the cut of a smooth-file; is it possible to form a clear comprehension of the shape and direction of the teeth without the aid of the lens? Certainly not. If, then, we form the tooth of the file, increased to twenty-four times the ordinary size, all the surfaces around it will be presented as practically clearly, as will enable one not even engaged in the special study of the matter, to form a clear idea of the shape of the tooth of the file. At the present moment we

submit to the appreciation and judgment of the interested public models of the cutting parts of files, drills and instruments for the cutting of the screw, outside as well as inside.

The three following lists will serve as the basis of the entire range of the collections, which represent all the instruments employed in work.

N. Models of drills and countersinks increased six times the ordinary size.

1. Model of cutting edges of a drill (double cutting) for drill-bow.
2. Model of cutting edges of a drill (one cutting) for drill-bow.
3. Model of cutting edges of a drill for crank-brace.
4. Model of cutting edges of a center-bit with long point.
5. Model of cutting edges of a center-bit with short point.

Remark. In models No. 1–5, are clearly shown the shapes of the cutting edges, and also the angles of the working surfaces. From an examination of these drills it will be easily seen the work of such instruments cannot be called good by reason of the irregular direction of the working surfaces.

6. Model of cutting edges of a drill, which edges have the favorable angles for the work.
7. Model of cutting edges of an American spiral-drill, distinguished by stability and exact work.
8. Model of cutting edges of a drill for boring turning-joints.
9. Model of cutting edges of a drill for half-ball borings.
10. Model of cutting edges of a fashion drill.
11. Model of cutting edges of a cone-countersink for wrought-iron and cast-iron.
12. Model of cutting edges of a cone-countersink for brass.
13. Model of cutting edges of a hemisphere countersink.
14. Model of a drill-stock with the cutter, showing its cutting edges and fastening.

O. Cutting parts of files increased twenty-four times ordinary size.

1. Tin-file.
2. Rasp-cut for lead and soft allayage of metals.
3. Sample of the first-course of files for hard metals, in order to show the angles of the working surfaces and cutting edges.
4. Sample of the first course and the second course, in order to show the beginning of file-teeth.
5. Sample of the first course of a smooth-file, in order to show the angles and form of the working surfaces.
6. Sample of the second course for smooth-files.
7. Sample of the second course of a fine cut rasp, in order to show the proportions of teeth.
8. Sample of the second course of an armfile, in order to show the proportions of teeth.

Remark. The three last samples show clearly and practically the size of the teeth of the most used files.

P. Screw-cutting tools, increased six times ordinary size.

1. Model of a screw-tap with conical nucleus and thread.
2. Model of a screw-tap with cylindrical nucleus and conical thread.
3–6. Models of screw-taps for nuts having holes not going through (complete assortment).
7. Model of part of a screw-plate for cutting external screw-threads.
8. Models of screw-dies with obtuse cutting angles.
9. Models of screw-dies with right cutting angles.
10. Models of Whitworth's screw-dies.

Q. Collection of instruments (about 90) employed in making apertures of various shapes.

R. Collection of instruments of measurement (43) used in studying the art of fitting.

S. Course I. Time for study, 240 hours. Samples (28) for the successive learning of the filer's trade.

T. Course II. Time for study, 240 hours. Samples (23) for the successive learning of the filer's trade.

U. Course III. Time for study, 240 hours. Samples (24) for the successive learning of the filer's trade.

Remark. The method of systematically teaching the art of fitting was first worked out in the Imperial Technical School of Moscow in the year 1868, and after eight years' trial has proved of immense advantage to the School itself, as well as to those of the Russian technical schools which borrowed that method of the Moscow Technical School at the time of the Petersburg exhibition of the year 1870.

In attestation of the utility of the proposed systematical method of teaching, we may observe that immediately after its being presented to the public in the year 1870, the Imperial Technical School received orders for similar collections from technical schools in Moscow, Petersburg and Odessa.

V. A bench, instruments and apparatus (13) for marking and lining machine-parts to be worked.

W. Collection of models (11) for the demonstrative instruction in the marking and lining; the red lines represent the geometrical axis, and the lines according to which the work must be carried out.

In all that precedes, I have endeavored to set forth, as clearly as I could, the general considerations upon which this system of shop instruction is based; to show that the solution of the problem has been approached from the instruction side, and not from the construction side, and in this consists its fundamental and thoroughly practical character, as part of a system of education. The system presupposes the student's ignorance, and begins at the foundation, both in theory and practice. Every step well taken from such a beginning is a clear gain, and the successive steps have only to be taken to arrive at the goal of success. The com-

plete demonstration, however, is seen in the results exhibited at Philadelphia — results which no mixed, or less systematic system could possibly produce.

Another value of the system is, that it is equally well adapted to the wants of each class, or grade, of students. If one wishes to be a mechanical engineer, and finds that he has the ability to master the highest theoretical questions involved, the amount of shop work will be graded to meet his needs; if, on the other hand, the student looks forward to the rank of a first class machinist, he will need more mechanical dexterity, and will therefore work out a larger number of examples, and be required to do less in the higher mathematical and theoretical studies.

It is also an exceedingly important feature of this system that the instruction shops are the least expensive to equip and maintain — and further, it is not necessary for the highest success of this instruction, that construction shops should also be immediately connected with the school, either as at St. Petersburg or at Moscow. The young engineer, or machinist, after graduating in such a course, will find no difficulty in completing his practical education in great manufacturing works, and probably under circumstances quite agreeable to those who have already spent all they could borrow to complete their chosen course of study. Further, the system applies equally to all industrial arts needing manual skill.

Even, now, the Department of Industrial Design, established in this Institute four years ago by the Trustee of the Lowell Institute, and which has in this short time attained such marked success, needs that its course of study should be materially widened and enlarged before it can take rank as a school of technical education in the textile manufactures. Practical instruction in weaving, the study of the textile materials used in the various fabrics, with the operations of spinning, scouring, fulling and finishing, should be added. Systematic school instruction in such specialties has so long existed abroad as to have become a recognized element in the quality of their textile manufactures. If Massachusetts expects to keep the lead in the quality of her industrial work, it must be done by the establishment of technical schools for teaching the manipulations, with such other special knowledge as each

particular art requires. In each case the details must be worked out simply as an educational problem, and the instruction put in charge of an expert specialist, who understands theoretically and practically the particular manipulation. With the same skill, energy and perseverance, as are needed to command success in the teaching of any subject, we shall not fail of corresponding success in the teaching of practical industrial art. With the ability to make will come the desire to create, to those who have the capacity to rise into the higher realms of their chosen art.

In the light of the experience which Russia brings us, not only in the form of a proposed system, but proved by several years of experience in more than a single school, it seems to me that the duty of the Institute is plain. We should, without delay, complete our course in Mechanical Engineering by adding a series of instruction shops, which I earnestly recommend. The whole matter turns upon getting the proper rooms. It is already clear that there are no other difficulties which can not readily be surmounted. With such shops once established, we shall also be prepared to offer instruction to those who wish to become constructers, rather than engineers, and especially to the large class of pupils to whom such a systematic training, properly supplemented with other studies, would prove a valuable foundation for further study, or for business. For these classes of students I propose the following outline of a

TWO YEARS' COURSE IN PRACTICAL MECHANISM.

To be admitted to this course the applicant must be at least fifteen years of age, and must pass a satisfactory examination in the following subjects: — Arithmetic, Geography, Spelling, Punctuation, English Composition, English and American History, and Algebra through simple equations.

FIRST YEAR.

		No. of Exercises	Hrs. per week
Shop Instruction		120	12
Algebra	1st half	45	3
Plane Geometry.	2d half	45	3
Rhetoric and Composition		90	3
Mechanical and Free Hand Drawing . .		90	3

SECOND YEAR.

		No. of Exercises	Hrs. per week
Shop Instruction		120	12
Algebra finished	1st half	45	3
Solid Geometry	2d half	45	3
English Literature		60	2
French		90	3
Mechanical and Free Hand Drawing		90	6

With the sets of samples of shop-work which will come to us at the close of the exhibition at Philadelphia, and the averages of the times needed to make each, taken from the shop records, and other information kindly promised by Dr. Peters, we shall be able to start with reliable data upon which to build.

JOHN D. RUNKLE, *President.*

Mass. Institute of Technology,
Boston, July 19, 1876.

SUPPLEMENTARY STATEMENT.

Since the issue of my report upon the Russian system of shop-work instruction for engineers and machinists, so many persons who have read it have asked me if I would give them a simple, concrete illustration of the system, that I fear I may have failed to make the matter entirely clear, and I will try, in a simple way, to present the idea, which would be entirely unnecessary if I could only show the series of instruction-samples made in the several shops, now on exhibition at the Centennial.

Clearly, the first step in practical mechanism is to teach the use of tools. Suppose that we have, say, fifty young men to teach. Now we can put the same tool or set of tool into the hands of each, and teach all together, as a class, or we can put a different tool or set into the hands of each, in which case the instruction becomes special to each, or individual instruction. In the first case, one teacher can systematically teach the whole class, and in the second case, to give each pupil equally good instruction, it will need as many teachers as pupils, without some of the teachers happen to be experts in the use of more than one set of tools; and at best it would clearly require in the second case several teachers. It must be plain that on all accounts it will be best to follow the class system, and teach all the use of the same tool or set of tools at the same time. It follows, then, that our shop must be fitted with fifty sets of tools, if this happens to be the number of students which can be well taught at once.

Now, it is plain that, to learn the use of the set of tools selected as the beginning of the course, a certain number of forms must be worked out, the number being determined by the amount of skill which it is important the particular class under instruction should acquire. Next, what should guide us in the selection of the forms to be worked out? If we examine a certain number of constructions, say machines made entirely of metal, we shall find that some of the parts are made or finished with the set of tools under consideration. Now, it is not necessary that we should select these

exact forms, but the whole end will be gained by devising and working out a series of typical forms, each of which will only vary from the actual ones to a limited extent, according to the special construction in which it may be needed. When the course in the first shop, say the filers' shop, is finished, the class is put into a new shop to learn the use of another set of tools, and so on until the use of all the tools used in the construction of wood and the metals is learned. It will be seen, then, that the samples made in each shop are made simply and only for instruction, in order that no conditions may enter to interfere with the system best adapted for this end. Next, it must be remembered that while the class is learning the manipulations of each set of tools, and thus learning at the same time to construct a *typical alphabet of mechanism*, the theory involved in the construction of the tools is systematically taught, — that is, the reason why each tool is so made and how it must be kept in order. Besides, each sample is made from drawings which the student has previously made, thus making this instruction also conform to actual practice.

Thus far the whole aim has been to give the student skill in the use of all the tools pertaining to the course, and now, and not before, he is prepared to be transferred to a construction shop. The Russian system is then a fundamental analysis of the problem of practical mechanism, and consists in teaching the theory and use of tools to classes of students in the same orderly and progressive way in which any other subject is taught, with the same supervision and instruction of a specially qualified teacher, holding each student to the same account and giving him the same credit as in other studies. In this way of teaching it the study of practical mechanism also becomes a discipline of positive value in a system of instruction. The theories involved in the construction of machinery have nothing to do with learning the use of tools, and the entire aim in a construction shop is the production of results based on the skill of the workmen engaged.

In addition to the foregoing analysis it will hardly be necessary to extend this letter, by showing in what ways a shop arranged for construction is unfitted for the class system of instruction in the use of tools, even if such a shop could be devoted to this purpose. I hope I have now made the Russian system plain to all who will take the pains to give the subject a little thought, and particularly from the educational point of view. As a system, it is fundamental, applicable to all industries needing manual skill, easily manageable as an element in a systematic course of instruction, economical of the time of the student, and of the funds of the institution. When the manual skill of the student has a commercial value, as it will have when he has thoroughly mastered the course upon the use of tools, then he will be of value in a construction shop; and it only remains to ask whether this shall be a school-shop or one of the great manufacturing establishments with which our country abounds. I presume that but little time need be spent upon the answer.

The students' skill is worth more to a manufacturing establishment than it could be to a school, even if manufacturing was one of the proper functions. Besides, under the best supposable circumstances, all the economic conditions upon which success in manufacturing depends could never be realized in a school-shop. Therefore our aim will be to build up the instruction-shops authorized by the Corporation of this Institute, and leave the young engineer or machinist to enter at once upon the broad field of his chosen career, for which he should be well fitted if he and his instructors have faithfully done their duty. It is not necessary for a school to

operate a railroad to teach its civil engineers, nor work a mine to teach its mining engineers, nor maintain a menagerie to teach natural history.

JOHN D. RUNKLE.

Massachusetts Institute of Technology,
Boston, August 21, 1876.

NOTE.—INDUSTRIAL ARTS IN THE PUBLIC SCHOOLS.

Extracts from "A Report of the Committee on Education, made to the House of Representatives of Rhode Island, at its January session, 1877, by Henry H. Fay, Chairman."

The subject is considered under the following heads:—

1st. The proper limit of free education.

2d. The importance of the High School in the system.

3d. The variety and kind of instructions in the schools.

4th. Industrial Art Education.

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Industrial Art Education.

Recognizing the fact that our public school system is not perfected beyond criticism or improvement, and that it is progressive in its nature, as well as elastic in its adaptation to the wants of the people, we must take cognizance of the sentiment quite prevalent in the community, that the results are not fully commensurate with the expenditure of money, and that the element of "practicality" is not as large a factor as it should be, in the great educational problem of the period. The importance of this opinion is acknowledged by the warmest friends of public education, and the popular demand has become so urgent, that at last it has found expression in that part of the resolution before us, requiring a consideration of the question of industrial art education in the public schools.

The subject of industrial education is by no means new, and were it only the *general* subject, referred to us, the task would be easier than now, since we are confined to the specific consideration of its aspect as an integral part of our present established system, or at least a supplement of it. We find that we are not the only inquirers upon this subject, as our investigations have developed the fact that, in all parts of our country, the subject has recently risen to prominence, and school-boards, educators, and legislators, are seeking for information. The National Board of Trade of the United States has interested itself in this matter, and in January last, sent a memorial to this General Assembly, as to each of the legislatures of the other States, reading as follows:—

"Your memorialists, representing merchants and manufacturers of the United States, beg leave respectfully to represent unto your Honorable body, that the interference and dictation of Trades Unions, and similar organizations, with the system of apprenticeship in earlier times prevailing in this and other countries, the active competition of foreign manufacturers with American industries in both home and foreign markets, and the increased attention being given by governments abroad, to the development and improvement of skilled labor, by instruction in science and art, as ap-

plied to mechanics and manufacturing, renders it in the opinion of this Board of great importance to our material progress, that suitable provision be made for the establishment of Art and Science schools in each of the several States, where workmen and their children may receive such technical instruction as will improve and create skilled labor, to the end that the poorer classes of society may become better fitted for a higher development of industry, and our mechanical and manufacturing interests be enabled more successfully to compete with those of other countries; therefore, your petitioners would respectfully pray that your Honorable body will adopt measures for the establishment of such a school, or schools, as is herein indicated, within the State of Rhode Island.

Respectfully submitted, by order of National Board of Trade,

FREDERICK FRALEY,
President."

JANUARY, 1877.

NEGLECT OF INDUSTRIAL EDUCATION, A NATION'S WEAKNESS.

The Universal Exhibition in 1851 at London, bringing together, for the first time, so extensive a collection of the industrial products of all nations, enabled each one to obtain a correct view of its own condition compared with that of others. The succeeding exhibitions in 1856, 1861, and 1867, furnished valuable lessons to all of the European countries, but especially to England, whose utter discomfiture at the Paris Exhibition in 1867, led to systematic inquiries as to the reasons for the more rapid progress made in other nations in many of those industries in which, everything else being equal, the English ought to excel. Government commissioners, composed of representatives of the educated professions, applied sciences, engineering, education and manufactures, were sent to the Paris Exhibition, and a deputation of over fifty skilled artisans, also, whose reports all concurred in the statement that the superiority of other nations in industrial products was due entirely to the greater interest given to the industrial education of their people.

These statements, admitting inferiority on their own part, noting the rapid advancement of other countries since previous exhibitions, and attributing it solely to the one cause, were most startling, and thoroughly alarmed all Englishmen who had patriotic pride in maintaining for their country precedence in manufacturing and mechanical industries.

They examined continental systems of industrial education, published elaborate reports, and at once adopted such educational measures as were deemed useful to them. During the last ten years since the Paris Exhibition, England has made wondrous efforts in this direction, and her advancement in the industrial arts was made manifest by the many exhibits of her productions at the Centennial Exhibition last year. Meanwhile, other European countries, taught by experience, had also improved upon the industrial schools, which had given them the advantage of at least one generation of workmen, and were determined to continue in the lead.

The French manufacturers did not fail to note the extraordinary exertions England was making to contend for precedence in industrial arts. They called the attention of the Government to the matter, and demanded increased educational advantages, in addition to those already in existence. A government commission, upon full investigation, learned that their system was very defective in comparison with that of Germany, and the result was

an energetic movement on the part of the State and of parties interested, which has, long ago, worked a great improvement in every branch of industry.

Switzerland, Germany, Austria, Russia, and other countries, were alike stimulated by the necessity of the case, to renewed interest in all that pertains to the advancement of the arts of industry, and their schools, which had been good, were made better, while those which had been best of all were advanced to a still higher standard. The process of improvement is still going on, and will continue to receive the utmost attention in each country that hopes to compete in the markets of the world with the products of her industry.

However satisfactory may be the present development of Rhode Island mechanical and manufacturing industries; whatever there may have been of inventive genius, artistic skill or business enterprise, to arouse feelings of pride in our achievements in the past, we must not lapse into a spirit of self-complacency, but rather take to ourselves the lesson from the experience of other countries, that no State can secure and maintain pre-eminence in mechanics and manufactures except by the systematic and thorough training of the young in the industrial arts; that the palm of superiority, by an unfailing law, will surely go to that country where the *hand of the laborer is guided by a cultivated taste and a scientifically trained intellect.*

From the last census of this State, we learn that in every 1,000 of our population, 560 are engaged in manufacturing or mechanical industries, and this fact in itself is sufficient to give us an interest in the great question of industrial education, and should lead us to the adoption of any measures that furnish a prospect of success in solving this great problem.

It will be interesting to briefly note what has been done in European countries, where, as we have stated, the interest in this subject has become synonymous with their self-interest, and where the competition of different countries has compelled attention to it, under penalty of banishment from the best markets of the world.

Industrial Education in Germany.

The system of general education in Germany is well known as being most comprehensive, and as having been successful in reducing illiteracy toward its minimum, but in its arrangements for industrial education it is equally broad and systematic. The proportion of the population engaged in mechanics and manufactures is less than in Rhode Island, but there is no place of any considerable size wanting in some sort of instruction having in view the various industries.

"Improvement" schools, "Real" schools, "Trade" schools, "Weaver's" schools, and special schools of many kinds, are found thickly scattered over the entire country, affording facilities not only for general, but for special, technical instruction that are unsurpassed. In the lower order of these institutions, there is a similarity to our elementary schools, with the distinction that, *invariably*, the strictest attention is given to instruction in *drawing*. Of the secondary schools, we give the curriculum of one of the best, styled the "City-trade School of Berlin." It was founded "to give a more appropriate education for the mechanic arts and higher trades than can be had through the courses of the other schools," and has the city of Berlin as its patron. The subjects of instruction are Religion, German, French, English, Arithmetic, Algebra, Geometry, Geography, History, Natural History, Physics, Chemistry, Technology, Writing, Drawing and Vocal Music.

The school is provided amply with laboratories, apparatus, and all the paraphernalia of instruction, and technology is taught by describing and illustrating the different arts and trades by models and visits to workshops of which there are none connected with the institution. Pupils enter after they are twelve years of age, and remain five years to complete the course. Higher than this in order, and forming the summit in the grade of industrial schools, is the Royal Trade Academy at Berlin, which embraces in its course far more advanced mathematical studies, and has extensive workshops connected with it, where various branches of practical mechanics are taught. The pupil begins with the making of a screw, and proceeds in regular order to the most difficult mechanical operations.

An Industrial Drawing School in Berlin, also, trains designers of patterns for printing silk, woolen and cotton tissues, and paper hangings, together with all the theoretical and practical branches of weaving.

Among the large number whose organization we have noted, the Royal School of Machinery at Augsburg, in Bavaria, is interesting, devoting, as it does, more time to the practical side of mechanics. The requisites for admission are a thorough knowledge of Algebra and Geometry, and a certain amount of practice in linear drawing. The pupils, who must be fifteen years old, pursue a theoretical course in higher Mathematics, Mechanics, Physics, Drawing, etc., but devote an average of three hours daily to the workshops.

The scholar is placed at a vise, and a coarse file and a piece of iron are given him. He practices first in filing planes at right angles, and then parellel to one another, then he does the same with a finer file. Nothing can be done superficially, and no one can go on to other work until he has been thoroughly successful. Next, he is practised in boring, cutting screws and in making faucets. Then comes the turning of round surfaces and of screws, smoothing off, etc., all of which is done with simple pieces of iron, out of which paper-weights, etc., are made. Other simple operations follow until the end of the course, when scholars are generally able to support themselves by work in any factory.

Enough examples have been furnished to show the general scope and variety of industrial schools in Germany, and while from the hundreds of them in operation, covering very many special trades and occupations, we might select some of unusual interest, we have not space for the details in this report.

In Austria, the agencies for the education of skilled labor are of various kinds, and increasing in number. They have, as in Germany, the "improvement" and the ordinary technical schools, but the great impulse which the art-industrial movement has received during the last twenty-five years, has called into existence new establishments of a similar nature, but largely devoted to special trades and industries.

These comprise theoretical schools and school shops, in which the practical and theoretical teachings are combined. The number of these schools has increased in the last five years from *ten* to *one hundred and thirty*. In the highest of the industrial schools, nearly one-third of the time is devoted to free-hand and geometrical drawing.

France.

France is equally aroused with her continental neighbors to exertions for increased facilities for industrial-art education, and has rapidly augmented the number of schools for the elementary training of the young in this

respect. While perhaps, failing to equal Germany in the universality of the system, she compares quite favorably in certain localities, and in the higher class of technical schools.

In 1805, when Napoleon was First Consul, he visited one of the government institutions and was extremely dissatisfied with the answers of the pupils about to graduate, as to their intentions for the future. These, he said, unless they entered the army, would become a "burden rather than an aid to their families." He had observed workmen in the manufacturing establishments who were experts in the manual labor of their trades, but deficient in the theoretical part, and hence he determined to change the course at this institution, so that it should be devoted to "the study of trades, with so much theory as is necessary to their progress." This was done by an order soon after published, and the result has been one of the most successful institutions in the world for this purpose, at Chalons.

The plan has been modified during the last few years, so that instead of teaching a number of trades, it is devoted to general mechanical industries for which theoretical knowledge is indispensable. The shops connected with it are the Pattern shop, Smithy, Foundry and Fitting shop. The pupils, who must be fifteen years of age, devote five hours or more daily, to the workshops, in which the general plan of instruction and practice is very similar to that previously described at Augsburg.

The general principles are, to make only one piece of the same kind, and to do all work, as far as practicable, by hand, and with the simplest tools. The school curriculum embraces Mathematics, Drawing, and the elementary branches.

Paris has numerous industrial schools of every grade, and throughout the country are found local institutions, often under the patronage of industrial societies, or established by individuals from philanthropic motives.

Notwithstanding all that had been done previously, a government report after the exhibition of 1867, states that "additional efforts must be put forth to maintain French industry at the level which it has reached, and enable it to meet the rivalry of other countries in fields, once by universal confession, exclusively their own."

The result has been, as in other countries, a period of remarkable activity in this direction during the last ten years, the beneficial results of which were seen in the display of industrial products at our Centennial, and will be far more evident at the next exhibition in 1878, on their own soil.

It would be a pleasing labor, if our time and space allowed, to note in detail the progress of other countries of Europe, and to give comparative views of their advance in industrial art education.

England, Holland, Italy, Sweden, Russia, and the other countries, have been actively working, and in each of them we find much to interest and instruct, but enough has been written to demonstrate the fact that in all of them the problem of industrial education is considered of vital importance, and that in its solution they are many years in advance of our own country.

Our own Country.

We have had in this country a few technical schools of a high order, whose pupils were instructed in the theory but not in practice, unless we except the chemical laboratory work. A prominent educator, connected with one of the best of them, remarked not long since: "Our graduates go out into the world with their brains well stocked with theories, but *with their hands tied behind them.*"

In occasional instances, institutions have been established where theory and practice were conjoined, as in the Worcester school, and the "Illinois Industrial College," with good results. The latter institution was established by the State of Illinois, in carrying out the intention of the act of Congress in 1862, giving grants of the public lands and prescribing, in return, the promotion of the "liberal and practical education of the industrial classes in the several pursuits and professions in life," as conditions accompanying acceptance. The State of Illinois has added liberally to the original fund, and the university now has property valued at nearly a million dollars, including a system of mechanical workshops and other paraphernalia for a complete industrial training.

In the State of Massachusetts much attention has been given to the subject, and throughout the State drawing has been taught in the public schools, being correctly deemed the true foundation of industrial art.

In Philadelphia, an association of private gentlemen organized the Pennsylvania Museum of Art, early in 1876, and took advantage of opportunities offered at the Centennial Exhibition to secure a large collection of industrial masterpieces to form the foundation of the museum, which like its prototype, the South Kensington Museum, in England, which within twenty years has revolutionized many branches of industry and created new ones, is expected to become an important aid to industrial education and culture.

The teaching of specific trades has often been urged, but the objections are so numerous, and the experience of the past so decidedly in opposition to such a plan, that aside from the difficulties arising from the option as to the particular trades to be taught, the expense of any general system would condemn it.

What is desired, is some system that will teach *the arts which underlie many industrial occupations*; something that will educate the hands and eyes; something that will furnish such a course of manual training as will enable our children, when they complete their course in the public schools, to secure some kind of employment, and not feel that they are incompetent to live, except "*by their wits.*"

If we can secure this, without limiting or abridging the usefulness of the system of education we now have in operation with such great success, we shall succeed in achieving for our day and generation and posterity, a blessing comparable in value with that which the founders of free public schools handed down to us.

In a careful study of very many systems of industrial instruction in Europe, we have found that all agree in one respect, namely, that *Drawing is an indispensable basis.* From the primary grades to the highest institutions of technology, Drawing is invariably a prominent feature of the curriculum. In all of these schools the same general principles are followed in uniting manual and mental instruction, and in familiarizing scholars with the use of tools. The details of instruction in the scores of schools we have studied, have differed more or less, but in nearly all of them the plan of manual instruction involved the methods of the apprentice system. In the school at Chalons, and also in that at Augsburg, there is an advanee upon the old methods, but in Russia, at the Imperial Technical School at Moscow, they have taken an entirely "new departure" in manual education, by conforming it strictly to the system and well established prineiples which have proved successful in developing skill in other arts and sciences. By this system, they *analyze the processes requiring manual skill, and teach each process by itself to a class.*

The first principles are taught, and exercises in practice accompany them, leading the pupil on from the simplest to the most difficult manipulations. Just as in teaching one to play upon the piano, the "scales" and simple exercises come first and receive entire attention, rather than set tunes, which are tried only after months of preliminary practice; or, as in Drawing, the pupil first practices upon straight lines and their various combinations, and then after long exercise, attempts anything requiring skill; or, as in penmanship, the first efforts are upon lines, curves and parts of letters, before writing words; so, in manual instruction at this institution, the systematic progress of the pupil is the paramount consideration.

The collection of implements and pieces of machinery contributed by the Russian government to illustrate the work done at that school, formed an interesting exhibit in Machinery Hall, at our Centennial Exhibition, and furnished to interested observers a definite idea of the plan, system and results obtainable from it.

Massachusetts Institute of Technology.

In response to the polite invitation of President Runkle, who had been informed of the inquiry of this Assembly in regard to industrial education, we spent a day with him, for the purpose of receiving a full explanation of the plan, and of having ocular demonstration of the results thus far achieved. The pupils, since the commencement of the lessons, had completed the course in "filing," and we saw, in the results of only *eighty hours* of practice and instruction, such exquisite workmanship as could not be surpassed by an apprentice of two years' experience in an ordinary shop. We found a class of thirty-two boys at work on a "chipping" exercise, with hammer and chisel, under the instruction and constant supervision of an expert mechanic, employed as teacher of practical mechanics, and it was easy to perceive that the class instruction in this branch of education was as systematic and simple as the teaching of a class in Arithmetic or Grammar in one of our best public schools. Our attention was directed to the fact that these shops are for *in*struction, and not for *con*struction. The object of the labor performed is not to produce salable articles, but to impart mechanical skill, and hence the student can here receive systematic instruction, proceeding from first principles to difficult manipulations, while in ordinary construction shops an apprentice is taught only those things which accord with the convenience and profit of his employer. The fact that the instruction is given to so many pupils at a time, in class, is a marked economical feature, carrying out, as in so many other respects, the analogy with our general system of mental training.

Our space forbids a full description of the many interesting details which came under our observation, as well as any account of the testimony already given by practical and expert mechanics, as well as by thoughtful and skilled educators, as to the wonderful results already secured in this experiment of an altogether novel method of industrial training, but we are fully satisfied that enough has been shown, in the few months of trial, to warrant us in the opinion, that in this well-tried system, at once so simple and so economical, we can find a way to the solution of the great question of the *adaptation of industrial education to our existing system of mental training in the public schools.*

DEPARTMENT OF MILITARY SCIENCE AND TACTICS.

President J. D. Runkle,
Mass. Institute of Technology: —

SIR: I have the honor to render the following report of the status of the military instruction at the Institute during the school year of 1875–6.

The changes, made at the end of the last school-year, were based upon experience of the past, and the desire on my part to fix its status before leaving the Institute so that it should be satisfactory to all connected with it and, at the same time, give useful results. The experience of the year has justified the changes made; so far as the drill alone is concerned, it seems now to be placed so as to be satisfactory both to Faculty and students, based upon the premiss that military instruction shall, *must* be given in good faith. The end of the school year has found the battalion in an increased state of efficiency of drill and discipline. The instruction to the second year class, by lectures and recitations, was incomplete for lack of time to do even the minimum amount of work necessary, productive of a result that can be at all satisfactory. I most earnestly request that the time allotted to the second year work be increased by six exercises, making only thirty in all during the year.

The officers of the battalion during the year were as follows:

Staff Officers ranking as First Lieutenants.

Adjutant: E. F. Williams.
Quartermaster: I. Kirk.
Signal and Ordnance Officer: W. O. Bradford.

Line Officers.

Captains: J. Rich, D. Pierce.
First Lieutenants: L. O. Towne, E. S. Draper, E. C. Miller.[1]
Second Lieutenants: R. Austin Robertson, Jr., Herbert Jaques,[2] F. P. Bronson.[3]

[1] Promoted previous to Centennial trip, vice Draper not accompanying the battalion.
[2] Vice Miller promoted. [3] Vice Robertson not accompanying the battalion.

Each and all of these officers performed the duties of their respective stations in a remarkably efficient and satisfactory manner; conscientious and impartial in the execution of their duties, they displayed great tact and judgment in their rather delicate relation with fellow students when assuming, *at stated times only*, the duties and relation of officers to subordinates. More than ordinary capacity was here required, and their ability to successfully perform the duties of their office at the school is a guarantee of their ability to perform similar or even duties of a *higher grade* in actual service.

CENTENNIAL TRIP TO PHILADELPHIA.

Many students were desirous of visiting the Centennial Exhibition, as it would present a vast field for study. On account of the expense involved, a large proportion would necessarily be prevented from attending, if only able to go individually. This objection would be obviated in a great measure if a number would unite in the movement. Enquiries were made to ascertain the cost, and it was found that if three hundred went, the expense of transportation to and from Philadelphia, board and lodging for two weeks would probably not exceed $25.00 per capita. The Corporation and Faculty therefore determined that the trip should be made.

The Corporation of the University of Pennsylvania courteously tendered the University Campus for a camping site. Efforts to get the necessary tents and camp equipage from the United States having failed, an act was passed in the State Legislature authorizing the loan of camp equipage to such schools as are, by the law of the State, required to give military instruction. We were thus enabled to procure the necessary outfit for camping. Through the intervention of Mr. Enoch Lewis, Mr. Phelan of Philadelphia kindly tendered us the use of sufficient lumber to floor the tents and for other purposes. Mr. Lewis procured for us, also, some engine head-lights to illuminate the Campus. Efforts were made to procure reduced rates of admission to the Exhibition, but they were unavailing.

Hon. Geo. B. Loring offered to us the use of the Massachusetts State Building as a place of rendezvous. Mr. and Mrs. Thomas Webster of Philadelphia were untiring in their efforts to secure for the Institute every facility which might be required. Professor Stillé, Provost of the University, placed at our disposal certain facilities which the University building afforded. Prof. Haupt, Prof. Richards and other Professors of the University aided us in many ways to perfect our arrangements.

Professor Robert E. Rogers, with the concurrence of the Medical faculty of the University, gave the use of a large room in the basement for a dining room, as also a number of other rooms for the use of such of the members of our Faculty as were accompanied by their wives. Prof. Ward and Messrs. Ross and Chamberlain did much, previous to and during our stay, to insure us every facility afforded in the building. Medical attendance and many courtesies were extended to us by Dr. Hammell, Superintendent of the Hospital of the University of Pennsylvania. A camping party, consisting of students, left for Philadelphia on June 1st. These laid out the camp, making the tent floors and pitching a large proportion of the tents. The labor performed by this party was severe. Arrangements were made for purchasing provisions and other necessary supplies, as also for the preparation and service of food.

On June 8th, at 4 P. M., the party, numbering something more than three hundred and seventy, started from the N. Y. & N. E. R. R. depot, in a special train for Norwich. The party consisted of members of the Corporation, Faculty, Graduates, former students, students and friends of members of the Institute. We were favored with being accompanied by a few ladies. At Norwich the boat was taken for Jersey City where the party arrived next morning at about 6 A. M. After some vexatious delay at this point, a special train conveyed the party to Philadelphia, arriving at about 10 A. M. The following regulations indicate the routine which was essentially followed during the encampment.

REGULATIONS.

1. The first three days will be devoted to a general inspection of the Exposition.

2. Thereafter the special subject of each day's investigation will be assigned by the head of the department in which the student is enrolled; and each student will be expected to conform to such directions as he may receive from the head of his department in the matter of his special work.

CAMP AND SANITARY REGULATIONS.

3. I. The daily routine will be as follows, viz.:

First Call for Reveille, at 6 A. M.

Reveille Roll-Call at 6.15 A. M.

At this hour every person, unless specially exempted, will be required to fall into ranks and answer his name unless sick. Bedding and blankets will be aired when weather permits.

Sick Call at 6.40 A. M.

Breakfast at 6.45 A. M.

Police Call at 7.30 A. M.

All persons will be required to aid in policing the grounds of the camp, and to put their respective tents in order.

Battalion Drill at 8.15 A. M.

(For the Institute Battalion only.)

Guard Mounting at 9 A. M.

The detail for the daily guard will be inspected and assigned to reliefs. The guard posted during the day will be detailed from the Battalion, and will be in four reliefs; each relief will stand guard three hours and fifteen minutes (in two tours), during twenty-four hours. Members of the guard will not be required to remain in camp, except while posted as sentries, and for one half-hour previous to their respective tours. *They must not, however, allow any chance to prevent their being in camp at the designated time for duty.* The guards posted at night will be detailed from students not in the battalion. Only one relief of the night guard will be permitted to go beyond the limits of the University grounds. The grounds will be thoroughly lighted, and a less number of sentries will be required at night; each relief will probably be posted only once during the night for not exceeding two hours.

Lunch at 12.30 P. M.

Dinner at 6 P. M.

Tattoo Roll-Call at 9.45 P. M.

All *Students* will be required to fall into ranks and answer their names, unless specially excused by the President. Applications for such absence must be made previous to 6 P. M. Blank forms may be procured of the Chief of Squad.

Taps at 10.15 P. M.

At this call all lights must be put out and perfect quiet observed in the camp. Whilst Graduates will not be required to answer their names at tattoo roll-call, nor to apply for permission to absent themselves from camp, they will be required to enter camp and retire noiselessly.

The before-mentioned hours may be changed if occasion requires. If it is found that the Exposition is open at night, the hour for tattoo roll-call will be so fixed as to permit students to remain until it is closed, and have ample time to return to camp. The hour for Reveille will, in that case, be also changed so as to allow at least eight hours for sleep.

4. All students will be required to perform a due proportion of guard, or such other camp duty as may be found necessary. These duties will be so arranged as to cause the least possible inconvenience and labor.

It is expected that the burden of each individual will be comparatively slight.

5. Failures to comply with the above regulations or any modifications of the same, or conduct reflecting upon the good name of the student, or of the Institute, will be met with dismissal from the camp, in which case the funds deposited will be forfeited.

To secure the uniformity of action necessary to avoid confusion, for purposes of police and cases of emergency, a Chief of Squad will be appointed for the members occupying each section of tents. An Assistant Chief of Squad will also be appointed to aid the C. of S in the performance of his duties, and to act for him in case of his absence. The Captains commanding Companies will act as C.'s of S. for sections A. and B.

DUTIES OF THE CHIEF OF SQUAD.

To call the roll at designated times and report unauthorized absence therefrom.

To superintend the police of the grounds in the immediate vicinity of the tents of his section.

To see to the proper arrangement of the tents, ventilation, airing of the bedding, proper disposals of debris, and necessary provisions against fire.

To report any needs for the comfort and well-being of his squad.

To ascertain if any members of his squad are unwell, and to cause them to report to the surgeon at sick call; in case of the patient's inability to move, the C. of S. will report the circumstances to the surgeon in order that the proper attention may be given.

To distribute at stated times the permits given each day for absence.

To aid at all times in the execution of such regulations as may be from time to time considered necessary.

The routine for Sunday will be as follows:

Reveille, Breakfast and Police calls, one hour later than during week days.
Battalion drill will be omitted.
Guard mounting at 9 A. M.
Dinner at 1.30 P. M.
Supper at 7 P. M.
Other calls same as week days.

One or two tents in each section will be assigned for bathing purposes, and tubs will be placed therein. If it is found that any waters in the vicinity can be used for swimming purposes, arrangements will be made to have a boat or other appliances for use, in case of emergencies. All are cautioned not to bathe immediately before or after eating, especially the latter.

A wagon was sent daily to the Exhibition Grounds with a luncheon which was served at the Mass. State building between the hours of 12 M. and 2 P. M. Every aid was given us by Gen'l Oliver, in charge of the building, and he was ever on the alert to add to our comfort and pleasure. Mrs. Vinton freely permitted us to use her kitchen with all its appurtenances. This arrangement enabled our students to enter the Exhibition Grounds in the morning and remain until evening without being put to any extra expense for a mid-day meal.

Hon. John Cummings, of the Corporation, who was in Philadelphia, aided us materially in getting permission from the authorities for the entrance of the wagon and servants, as also in other matters.

The matter of feeding so large a number with but improvized appliances and with persons inexperienced in such work, was one of great difficulty. Many of those to be served were not able themselves to perceive the difficulties inherent in the work, and expected as much as if the party consisted of but twenty or thirty. The difficulties were overcome in a measure and only the most fastidious remained dissatisfied with the commissariat. With the experience derived from this, great improvements now appear to be feasible. All however was done that was possible under the existing circumstances and considering the pecnniary limits no complaint can be reasonably made

of the fare. Messrs. Blodgett and Knapp of the Institute, attended to the purchase of the provisions and superintended the management of the dining room.

Considering the great change involved, and the experience of strangers generally in Philadelphia during the exhibition, the health of the party was exceptionally good. We were favored in having with us Dr. Sabin of Brookline, who, acting as surgeon of the expedition, was devoted in the performance of his duties, not sparing himself, treating with such skill that in most cases twenty-four hours sufficed to produce a radical cure. His pleasing, cheering, tender ways did quite as much in producing the desired results as the medical prescriptions given.

In establishing regulations for, and enforcing the discipline of the camp, it was the aim to have the minimum restriction and military work consistent with maintaining good order and securing the proper sanitary conditions necessary for the health and comfort of all. As the object of the expedition was to study the exhibition, as the change of locality, climate, water, and mode of life were in themselves trying, every effort was made to enable the students to economize their vital energies for the work in hand. The military work and display was reduced to the minimum, and in every case was made to yield to the foregoing considerations. The conduct of the students was exceptionally good and the subject of general commendation. I do not think it is possible to gather from any other college or school in the United States, so large a body of young gentlemen who would so earnestly enter into the spirit of their work, accomplish the object of the expedition and have conducted themselves with the same degree of propriety and consideration. As the members detailed for daily guard were not obliged to remain in camp, but report for duty in time to be posted on a specified relief, reliance was placed entirely on their sense of honor and duty.

The adjutant of the battalion, Mr. E. F. Williams, aided by the Sergeant Major, Mr. F. R. Loring, performed the duties of their office in the issuing of orders and making details, etc.,

most efficiently. This involved no little labor and responsibility, requiring great judgment and tact on the part of the Adjutant.

The Signal and Ordnance Officer, Mr. W. B. Bradford, aided the commandant materially as a staff officer in the execution of many details of the camp.

In the management of the camp and in the execution of all necessary regulations, efficient aid was given by the chiefs of sections, their assistants and the commissioned officers of the battalion. The following is the list of the chiefs of sections and assistant chiefs of sections, viz.:

	Chief of Section.	*Assist. C. of Section.*
Section A,	Capt. Pierce.	1st Lieut. E. C. Miller.
" B,	" I. Rich.	" L. O. Towne.
" C,	C. F. Lawton.	J. P. Gray.
" D,	T. E. Schwarz,	C. T. Main.
" E,	J. B. Gardner,	A. Austin.
" F,	W. H. Shockley,	C. A. Church.
" G,	Adjt. E. F. Williams.	

For the entertainment of the students, a piano was rented and a number of musicians were hired to play every evening. The dining room was cleared and hops were held therein. The students of the University attended bringing their lady friends. Many lady friends of the students, present in the city also attended. All this added very much to the pleasure of our students and caused a larger proportion to remain in camp at night than would have otherwise been the case. The students of the University displayed a kindly and hospitable disposition to our students, exerting themselves to add to their comfort and pleasure in many ways. In recognition of this, a reception was given to them and their friends on the night of June 21st. We were favored by the presence of a large number of ladies. The camp was illuminated and some tent floors having been placed together, out of doors, dancing took place on these and in the dining room. The camp was enlivened until after midnight by the presence of nearly twelve hundred

ladies and gentlemen. The entertainment was eminently successful as such.

On the 22d of June a number of the party left for their homes, and on the 23d the larger proportion left returning by the same route they came. Supper and breakfast were served on board the boat by servants returning to Boston with the party. They arrived in Boston somewhat fatigued but in good health and spirits, none regretting having made the trip.

As it was impossible to break up the camp at once, and it was necessary to keep up a portion of it, whilst the rest was being removed, camp equipage packed and grounds cleared, about fifty professors and students remained until June 29th and 30th. A small camping party remained until July 5th, when they finally departed.

In the preparation for the expedition and encampment, in the labors pertaining to his office as Quartermaster during the encampment, in the closing up its affairs and return of the large amount of camp equipage and other property, Mr. E. H. Gowing displayed marked ability and business capacity. The duties were laborious and difficult and their satisfactory execution deserves more than a passing notice. He was assisted by Messrs. W. B. Fisher and Jas. H. Tibbits.

To the gentlemen mentioned not connected with the encampment, thanks are due for the interest and kindness shown. I wish to express my warm appreciation of the efficient and unselfish manner in which the students occupying the various offices of the encampment performed their laborious and sometimes otherwise thankless duties. These were of such nature that in many cases the casual observer would not know of their existence nor of their real necessity and importance. Without this unselfish devotion to their duties the encampment could not have been successful; they therefore deserve the thanks of the Institute. As to the results of the expedition to the school from an educational point of view, you, Mr. President, are more capable of speaking.

The expedition to the Centennial Exhibition will undoubtedly

be considered a noteworthy event in the history of the Massachusetts Institute of Technology, and I am pleased that I should have been able to take part therein.

As this is my last report to you previous to severing my official connection with the Institute, you will pardon me for adverting to matters not within my field of work, but which I am impelled to mention by my interest in the welfare of the Institute. In my report of last year, I referred at length to the subject of physical culture, its especial necessity to students, the aid given thereby to mental culture and the great benefits derived from its introduction at Amherst College. I cannot advance any new arguments in the matter. I am most strongly convinced of its importance in all schools. Especially is it necessary at the Institute. Any time and money devoted to this, as a regular part of the curriculum of the school, will produce more than commensurate results and will add much to the future success and reputation of the school, — the spirit of earnest work which now pervades all who enter it will not so frequently reduce their physical strength — they will add to it, do more vigorous mental work and live long enough to accumulate and increase the knowledge and mental vigor necessary for the attainment of success; the Institute will be more likely to be decorated by laurels won by its Graduates. I most earnestly entreat a careful consideration of this subject, being, as it is, of such *vital* importance.

During my tour of duty at the Institute I have observed that a large number of its Graduates, without influential friends, find great difficulty in securing professional employment soon after graduation. With these especially, this is a matter of prime importance. It is always the most difficult step to get the *initial* employment. The Graduates of the Institute are so well prepared, graduation necessarily conveys with it such capacity and preparation, that no doubt can be felt as to the future of the largest proportion. The prosperity of the school is inseparable from the prosperity of its Alumni. The sooner these become prominent in the Engineering and Scientific

world, the more quickly will the Institute acquire the reputation which is its due, and the material prosperity which will be brought to it by the aid of its Alumni. It will be enabled by them to enlarge and improve its field of work and to increase its attendance.

This may be brought about primarily, by the efforts of the members of its Corporation and its Faculty, by using the influence and interest which many of them possess in the business and educational world. Secondarily and finally this work may be taken up and carried on by the Alumni Association. Each Graduate will feel it his duty to the school to endeavour to secure employment for other Graduates. No one can be so placed but that opportunities will present themselves; a strong esprit de corps will be created. They will not so often feel that their interest in the Institute closes with their immediate connection, and both the school and its students will be benefitted.

I am extremely desirous of seeing the work, which I have endeavored to shape so as to give the best results within its circumscribed limits, carried on successfully. In order that it may attain the highest degree of success possible within those limits, it is absolutely indispensable that it should receive the ungrudging, unqualified, hearty support of the Faculty. Let it be considered that the military instruction is inevitably in the Institute as a necessary part of its creation and existence — that experience has shown that it is not detrimental to its interests as a scientific school if properly managed and circumscribed — that it is desirable to make this portion of its curriculum as thorough, within its apportioned limits, as other work of the school — that it will be of benefit to the nation in the emergency of a war — that it is the desire to cause this work to be carried on in good faith with the Government — that it will be considered less a hardship by the students if they observe that the work is inevitable and it receives the hearty support of the Faculty. For these reasons, therefore, I most earnestly make the parting request not alone to accord the Military

instruction a passive but an active and generous support — that efforts be made to make it absolutely attractive to the students. A careful consideration of this subject will surely indicate that such a course is the only one open, in order to give stability to the department of military instruction, prevent its being detrimental and a source of constant irritation.

In parting from you officially let me express my appreciation of your unfaltering support and the courtesy with which I have been almost invariably treated by the members of the Corporation, Faculty and Students of the Institute, during nearly four years of duty, which necessitated, on my part, a course absolutely distasteful and obnoxious to many. Amongst the students I have found a very large proportion, who, if life is spared them, will take a high standing in any field of work which they may undertake — I have found that the general moral tone of the students, as a body and as individuals is higher than in any other school that has come under my observation. In reviewing the time spent by me at the Institute, I can not help but feel that, balancing all things, it has been both pleasant and profitable to myself. I will always feel an interest in its welfare, and will endeavor to further it and the interests of its Students and Graduates whenever the opportunities to do so can be seized.

I am Sir,

Very sincerely and respectfully,

E. L. ZALINSKI,

1st Lieut. 5th U. S. Artillery.

LOWELL DEPARTMENT OF INDUSTRIAL DESIGN, FOR 1875–76.

President J. D. Runkle: —

At the close of the fourth year of my department, I have the honor to submit to you the following report of the progress attained by my pupils. Of the entire number of graduates, twenty-four, twenty-two have received situations as designers and finishers in different mills in the New England and Middle States. During the past year the school has had two public exhibitions, one in Boston, the other in Philadelphia, at the Centennial Exhibition. At both places the exhibitions were well attended and a large and varied collection of patterns was displayed. At Philadelphia we were awarded two diplomas, one by the Women's Department; the other by the General Commissioners. The reasons assigned by the latter for their bestowal are as follows: "For the beauty, and general merit of the drawings exhibited; for their useful effect on various important industries and especially for their bearing upon technical education in general." The advanced pupils have the privilege of exhibiting their designs to manufacturers and frequently succeed in disposing of their patterns.

I would suggest the necessity of more materials as samples of the style of the season, such as novelties in oil cloths, prints, laces, cretonnes, carpets and fancy woolen goods. From these we obtain ideas of the prevalent style and thereby are enabled to suit the market. At present we have only the sample patches from Claude Frères of Paris. After long exertions I have succeeded in obtaining a loom, on which I propose to

teach weaving to my pupils. By the aid of the loom, I am enabled to supply a deficiency which has long existed in my department; I can now furnish designers for silk and woolen goods. Without a loom such a thing is impossible; as a designer for silk and woolen goods must thoroughly understand weaving, and the art of putting a design on the loom. During the last few months I have introduced ceramic painting and the decoration of pottery; the young ladies are much interested, and bid fair to make a gratifying success in this branch of art. The following is a list of the pupils in situations, and the place of employment of each.

James L. Folsom	Hartford Carpet Co., Thomsonville, Conn.
Alex. Johnston	Pacific Mills, Lawrence.
Sam'l Hudson	" " "
Everett Authes	Manchester Print Co., Boston.
Mary Jefferson	" " " "
Elizabeth Mendum	" " " "
Carroll S. Faunce	Hamilton Woolen Co., New York.
Chas. H. Cowdrey	Oriental Print Co., Boston.
William Schroeder	" " " "
Howard G. Hinckley	Merrimac Print Co., Boston.
S. R. Eaton	" " " "
Edgar Eames	" " " "
Minnie Ricker	Hamilton Print Co., Boston.
Harriet A. Parker	Roxbury Carpet Co., "
Henry P. Mabille	American Print Co., New York.
Annie D. Stimers	Sprague Print Co., " "
John H. Tarbell	Donnell Manufac. Co. " "
Kate T. Simonds	David Browne & Co., Philadelphia.
Edward Williams	Lithographer, Boston.
Henry Morse	Carpet Mills, Maine.
Ernest Pierce	Pacific Mills.

Respectfully submitted,

CHARLES KASTNER,

Director.

DEPARTMENT OF ARCHITECTURE.

President Runkle,

DEAR SIR: — The department under my charge was fully described in your Report for the year 1875, and but little change has since taken place in it. The only unusual event during the year 1876 has been the exhibition of the work of its students at the International Exhibition at Philadelphia. No drawings were made expressly to be exhibited, the instruction following its usual course, but in addition to those made by students still in the school a certain number were obtained from students of previous years, so that we were able to make a very fair presentation of the work of the Department. The result was unexpectedly satisfactory, and the drawings attracted a great deal of favorable attention especially on the part of visitors from abroad. They were quite unlike anything else in the Exhibition, the American schools not undertaking to cover the ground that we go over, and the foreign schools of similar grade not exhibiting their work. Towards the close of the Exhibition the American Institute of Architects held its annual Convention in Philadelphia, and a valuable opportunity was thus offered of making known to the profession the real issue of our undertakings. At about the same time information was received from Col. J. J. Marin, Commissioner from the King of Spain, that the splendid collection of casts of Moorish and Spanish architectural detail which formed a chief point of interest in the Spanish Pavilion was to be distributed among the educational museums in different parts of the country, and that in addition to those sent to the Museum of Fine Arts in Boston a portion of them would be sent to augment our own collections.

After the close of the Exhibition, accordingly, about fifty pieces of Saracenic and Renaissance detail were delivered to our agent in Philadelphia and are now hung upon our walls. Col. Marin was also good enough to accede to my suggestion, and send us a very interesting set of drawings made in the Municipal Schools of Madrid. At the same time we received from the agents of MM. Dûcher et Cie, of Paris, through M. Albert Levy of New York, six screens, covered with examples of their architectural publications, of great interest and value, and from Messrs. Galloway & Graff, of Philadelphia, a large vase in red terra-cotta, from an original in the British Museum.

Almost all the students then belonging to the Department, with as many as a dozen former students, joined the expedition organized by the authorities of the Institute and encamped for a fortnight on the grounds of the University of Pennsylvania. The points of professional interest proved too numerous to admit of systematic study during so short a period, and in respect of tangible results the undertaking so far as concerns this Department disappointed my expectations. But it was none the less a success, and the young men found that although they had not much to report in regard to the special topics assigned to each, it saved them from wasting time to have their attention thus definitely fixed upon special points of real interest.

Besides the gifts above mentioned a number of volumes of professional interest have been received from Mr. Geo. B. Emerson, from Mr. E. C. Cabot, and from Mr. G. J. F. Bryant, and the Royal Institute of British Architects in London and the Société Centrale des Architectes in Paris continue regularly to send us their publications. We are also indebted to Messrs. Hartwell & Swasey for a large and interesting model of a church erected by them at Fall River. No other important additions have been made to the library or collections, but a good deal of work has been done in re-arranging and cataloguing, and in binding and re-binding books, and the number of diagrams used in the lectures has been considerably increased.

The collections, though thus deficient in new material and

without the means of supplying old deficiencies which become daily more apparent, prove more and more serviceable as the work of the department is so adjusted as to bring them into more constant use. As their character and value become better known in the community and as interest in such subjects increases, their range of service becomes every year more extended, the books, drawings and photographs being freely lent to responsible persons when this can be done without inconvenience to ourselves.

But in this respect as in every other the usefulness of the department is greatly impeded by the limitation of its resources.

The number of students, both Regular and Special, has been larger than ever before and of better quality, the two years Special Course affording opportunities for young men who have already had an office training to come and get the training that an architect's office cannot give, of which an increasing number of such students from various parts of the country show a disposition to avail themselves.

I am, very respectfully, yours,

WILLIAM R. WARE.

MINING EXPEDITION TO PENNSYLVANIA.

President Runkle,

DEAR SIR: —Though the long study of the Centennial Exhibition had made considerable drafts on our time, strength, and money, it seemed advisable that the mining students, before our return to Boston, should take advantage of our nearness to the anthracite region and spend another week in seeing something of the great mineral resources of Pennsylvania *in situ*. Accordingly we made up a party of thirteen, of the classes of 1876 and 1877. Arranging for some to join us on the way, ten of us started early Monday morning, June 26th, by the North Pennsylvania Railway, and arrived betimes at the busy town of Bethlehem. Here a walk of some four miles, under a blazing mid-day sun, brought us to the Bethlehem zinc mine, noted for being drained by one of the most powerful pumping engines in the world. The mine itself is of a remarkable character and its irregular veins were yielding a good supply of very compact blende. But the huge engine had to be kept in unceasing motion to render the deposits accessible, and the cost of working had become too great as compared with the contract price of New Jersey zinc ore, and not long after our visit the mine was closed not to be reopened probably for a generation to come. So it seems we had improved almost the last opportunity to go through the intricate, dripping passages of the Bethlehem zinc mine. Returning to a very late dinner in town we afterwards spent some time in the extensive zinc

smelting works and took up the rest of the long day in watching two "blows" of Bessemer iron in the immense and well appointed works of the Bethlehem Iron Company.

A night ride brought us to the closely hemmed in town of Mauch Chunk, with its never ending rumble of coal trains. Tuesday morning we found our way to the romantic Glen Onoko all aglow with its lavish profusion of wild rhododendron flowers. Here was scenery that might well stir the hearts of even such delvers in the earth as ourselves, and when we had scaled the heights above and were enjoying the broad view from Lookout Point it was resolved, in our by no means temporary enthusiasm, that a visit to Glen Onoko may make an entirely proper and legitimate part of a mining excursion. The returning train brought us back to Mauch Chunk in time for a forenoon trip up the famous Switch Back railway to Summit station. We took a half mile walk along the surface debris of the burning coal mine and crawled down into one opening far enough to find an ice pavement. Little indication was there of the combustion which has been going on for years, except one or two very faint vents of vapor through cracks at the surface of the ground. When dinner was over we had to hurry a mile down hill, baggage in hand, to catch the train for Tamaqua. At dusk we found good quarters in Pottsville, and while waiting for the arrival of the rest of our party from Philadelphia some of us visited the only blast furnace then at work in town.

The next day we joined the excursion party of the American Institute of Mining Engineers, and enjoyed a rare opportunity of seeing the best parts of the anthracite region. Leaving the excursionists at Reading we waited some time for the westward train, and reached Harrisburg soon enough to have some four hours' sleep before a very early start for Johnstown. So the ascent of the Alleghanies and the ride around Horse Shoe Bend was made by daylight after a breakfast at Altoona, and our westward destination was reached before noon. Johnstown proved a much more comfortable place than the dingy aspect of

things there would lead one to expect. We were very courteously received at the extensive works of the Cambria Iron Company, which were in full operation, turning out two thousand tons of rails per week, notwithstanding the great depression in the iron business. But with coal and iron ore on the spot and each costing, ready for use, considerably less than a dollar a ton, this Company may well defy competition. Here was a fine chance to study in one compact area several three foot semi-bituminous coal seams, a thirty inch deposit of iron carbonate, the wholesale roasting of the ore, the manufacture of fire bricks, coal washing, the skilfully planned coke kilns with steam discharging-ram, blast furnaces, puddling furnaces, rail mills, and Bessemer converters, running day and night. Mr. Fulton, the engineer of the Company, devoted his whole time to us for a day, and having studied his work as an investigator was able to give us much new information at first hand. Crouched down in mine cars we had a lively two mile ride underground through the horizontal upper coal seam, and another through the ore bed. We are much indebted to the Superintendent and his several assistants for their kind attention and hearty aid during our very instructive and pleasant two days' stay.

More time might have been well spent, but it was possible, by starting homeward Friday night, to reach Boston before the national holiday and avoid the extraordinary rush of travel to the grand centennial celebration in Philadelphia. As it was, we could not all secure seats in the cars till some of our fellow passengers got out at Cresson Springs. We reached the old camping ground, where a few tents were still standing, in season for breakfast Saturday morning. Here the party was resolved into individuals, some staying longer in Philadelphia, some going on at once to New York, some taking another look at the Exhibition before embarking in the noon train for home. The approaching fourth of July had caused us to crowd a proper fortnight's work into six days, but after a few days' rest I believe no one felt the worse for our flying trip.

I must not close without grateful mention of assistance rendered by Mr. Felton and Mr. Gowen, whereby transportation on the Pennsylvania Central and Reading railroads was secured on the most favorable terms.

Respectfully yours,

JOHN M ORDWAY.

APPENDIX.

CENTENNIAL CATALOGUE.

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY exhibits:—

1. Two Photographs of its Buildings, in Boylston Street, Boston, and twenty Photographs of the principal lecture-rooms and laboratories.
2. A complete set of printed documents describing its work.
3. A set of elementary Drawings made by students of the First Year in portfolios.
4. Drawings of students in the Department of Civil Engineering, framed and in portfolios.
5. Drawings of students in the Department of Mechanical Engineering, framed and in portfolios.
6. Drawings and Designs of students in the Department of Architecture, framed.
7. Drawings, Models and Samples, illustrating the professional work in the Department of Mining and Metallurgy.
8. Models, Instruments and Papers, illustrating the professional work in the Department of Physics.
9. Drawings and Designs made by pupils in the Lowell Free School of Industrial Design.
10. Graduating Theses in the Departments of Civil, Mechanical and Mining Engineering, Architecture, Physics, Chemistry, Natural History, Science and Literature, and Philosophy.

The exhibition consists entirely of work done in the school, and the apparatus of instruction is not exhibited except so far as it has been devised or made by professors or students.

THE DEPARTMENT OF CIVIL ENGINEERING exhibits:—

I. Sixteen framed drawings.

II. Ninety drawings in portfolios.

The subjects of these Drawings embrace Railroad Surveys, Topography, Stone Cutting, Bridge and Roof Construction, and Original Designs for Structures.

III. Thirteen theses by members of the class graduating this year, as follows: —

1. The Providence, R. I., Water Works, by Thomas Aspinwall, Jr., Brookline, Mass.
2. The Merrimac River Bridge, at Nashua, N. H., by Thomas W. Baldwin, Bangor, Me.
3. The West Chester Park Bridge in Boston, by Joshua B. F. Breed, Louisville, Ky.
4. A Review of the Buffalo Water Supply, by Harry T. Buttolph, Buffalo, N. Y.
5. The Front Street Bridge in Worcester, Mass., by Frederick K. Copeland, Fairhaven, Vt.
6. The Broadway Bridge in Boston, by John R. Freeman, W. Bridgton, Me.
7. The Superstructure of the East River Suspension Bridge in New York, by Martin Gay, Staten Island, N. Y.
8. The Albany Street Bridge in Boston, by Frederick W. Hodgdon, Arlington, Mass.
9. The Iron Bridge over the Merrimac River at Tyngsboro', Mass., by Arthur L. Mills, Everett, Mass.
10. Design for a Wrought Iron Post Truss, by Henry Raeder, Hyde Park, Mass.
11. Draw in the West Boston Bridge, by C. Leon Rich, Morristown, Vt.
12. The Eastern Avenue Swing Bridge in Boston, by Henry M. Waitt, Nantucket, Mass.
13. A Highway Bridge at Haverhill, Mass., by Henry B. Wood, Woburn, Mass.

THE DEPARTMENT OF MECHANICAL ENGINEERING exhibits: —

I. Four hundred and thirteen drawings and tracings framed and in portfolios, as follows: —

Boilers.

1–21	A Martin Boiler.	4 Drawings, 17 Tracings.
22–25	Boiler of Providence Pumping Engine.	4 Tracings.
26–28	Boiler of Monitor Nahant.	3 Tracings.
29–30	High Pressure Marine Boiler.	2 Tracings.
31–45	Cunningham Stationary Boiler.	15 Drawings.

Stationary Engines.

46–82	Harris Corliss Engine, Elevation.	2 Drawings.
	" " " Details.	12 Drawings, 5 Tracings.

83–85	13 HP. High Pressure Engine.	1 Drawing, 2 Tracings.
86	Beam Engine.	1 Drawing.
87–90	Steam Cylinder and Valve.	2 Drawings, 2 Tracings.

Marine Engines.

91–94	Beam Engine.	4 Tracings.
95–100	Engine of Steamer Humboldt.	6 Tracings.
101–109	Launch Engine.	6 Drawings, 1 Tracing.
110	Marine Engine.	1 Drawing.

Locomotive Engines.

111–160	Elevation and Details.	9 Drawings, 41 Tracings

Steam Pumps and Pumping Engines.

161–169	Blake, Lawrence and other Pumps and Pumping Engines.	9 Tracings.

Hydraulic Machinery.

170–175	Cranes and Presses.	5 Drawings, 1 Tracing.

Water Motors.

176–186	Turbines and Breast Wheels.	2 Drawings, 9 Tracings.

Screw Propellers.

187–193	Various examples.	17 Tracings.

Machine Tools, etc.

194–197	Upright Drill.	4 Drawings.
198	Boring Machine.	1 Drawing.
199–206	Car-axle Turning Lathe.	8 Drawings.
207, 208	Steam Hammer.	2 Tracings.
209	Steam Derrick.	1 Drawing.
211, 212	Section of Mill.	2 Drawings.
213–219	Stub End.	7 Drawings.
220–222	Cross Head.	3 Drawings.
223–226	Eccentric.	2 Drawings, 1 Tracing.
227–251	Screws, Cams, Cranks, etc.	24 Drawings.
252–265	Driving Pulley. Boott Mills.	14 Drawings.

Toothed Wheels and their Construction.

266–280	Sector Gears.	15 Drawings.
281–294	Bevels.	14 Drawings.
295–337	Gear Templets.	43 Drawings.
338–341	Sector Gears.	4 Drawings.
342–359	Bevel Gears.	18 Drawings.
360, 361	Gear Teeth.	2 Drawings.
362–370	Rolled Curves.	9 Drawings.
371–382	Course in Gear Construction.	12 Drawings.
383–389	Gear Templets.	7 Drawings.
390–413	Spur Gears.	23 Drawings, of which seven are designs.

These Drawings are not exhibited as evidences of skill in Draughtsmanship, but as graphical reports of some of the information which the Students acquire during their professional course. They are the work of Students, and are about half the drawings made by them during the year.

II. Seven Theses by the Graduating Class.

1. Locomotive Engineering, by Francis E. Galloupe, Lynn, Mass.
2. Steam Boilers, by Clarence L. Dennett, Beverly, Mass.
3. Screw Propellers, by Charles F. Prichard, Marblehead, Mass.
4. The Efficiency of Marine Engines, by Charles T. Main, Marblehead, Mass.
5. Design for a Mechanical Laboratory, by Aaron D. Blodgett, Boston, Mass.
6. Shafting and its Fittings, by Theodore J. Lewis, Philadelphia, Pa.
7. Paper Mills and Machinery, by Sumner Hollingsworth, South Braintree, Mass.

THE DEPARTMENT OF ARCHITECTURE exhibits 77 drawings in 60 frames, illustrating the instruction in Architectural Drawing and Design. These drawings are the work of the regular and special students during the last year and a half, and comprise about a tenth part of similar drawings made during that time by about fifty different students.

1. The Drawings numbered 1 to 5 show the Elementary Work taken up at the beginning of the Course. Every student does similar work to this, or its equivalent.

2. The Drawings numbered 6 to 11 are exercises in Architectural Drawing, being fac-simile copies of original drawings, made in the *Ecole des Beaux-Arts*, in Paris, now in possession of the Department.

3. The Drawings "from prints" numbered 12 to 19, involve more independent work than the foregoing, the originals being in most cases small line drawings, without shading or color.

4. The Drawings numbered 20 to 24, are made from free-hand sketches of buildings in Boston, generally without exact measurements. This work is done by the more advanced class.

The work already mentioned is mostly done during the months of October and November, at the beginning of the school year.

The six remaining months, from December to May inclusive, are mostly occupied with a series of architectural problems, made in accordance with written programmes, specimens of which are given.

The subjects of these drawings are: —

1, A Porch; 2, A Campanile; 3, A Summer House; 4, A Pavilion between two Bridges; 5, A Billiard Room and Boat House; 6, The Employment of Six Columns; 7, A Temple Tomb; 8, A Staircase under a Vault

or Dome; 9, The Restoration of a Pompeiian House; 10, A Lamp Post; 11, A Fountain; 12, A Memorial Library; 13, A Memorial School House; 14, A Railroad Station; 15, An Artist's House; 16, A Catholic Church; 17, Water-Works in a Park; 18, A Dwelling House; 19, A Farm Barn; 20, A School of Architecture.

5. The rest of the drawings, numbered 25 to 60, illustrate this work.

This Department exhibits two Graduating Theses, illustrated by drawings.

1. A Railroad Station upon a Bridge, by William B. Dowse, of Boston, Mass.

2. Reservoir and Water Works in a Park, by Amos J. Boyden, of Foxboro', Mass.

THE DEPARTMENT OF MINING AND METALLURGY exhibits:

1. Two Sketches of the Mining Laboratory.
2. Two Sketches of the Metallurgical Laboratory.
3. A Novel Assay Ore Dresser.
4. A set of Samples of work done by this Ore Dresser.
5. A Tabular Statement of the System of Ore Dressing used at the Institute.
6. A set of Samples taken from the working of a ton of Ore with the Mining Machinery in the Laboratory.
7. Specimen of Lead from the Practical Treatment of an Argentiferous Lead Ore from Burleigh Tunnel, Colorado, extracted by S. James, Jr., in the Metallurgical Laboratory, from 1100 lbs. of ore.
8. Specimens of Lead from the Practical Treatment of an Argentiferous Lead Ore from the Merrimac Mine, Newburyport, Mass., extracted by W. D. Townsend and Julius H. Susmann, in the Metallurgical Laboratory, from 784 lbs. of the ore.

Six Graduating Theses.

1. The Newburyport Silver Lead Mine, by J. H. Susmann and W. D. Townsend, Boston.
2. The Richmond Blast Furnace, by Thomas W. Robinson, Chicago, Ill.
3. A Report on the Vershire, Vt., Copper Mine and Ore, by R. H. Gould, East Cambridge.
4. The Port Henry Iron Foundry, by C. F. Allen, Cincinnati, O.
5. The Metallurgical Treatment of an Argentiferous Galena from Burleigh Tunnel, Colorado, by S. James, Jr., Cambridgeport, Mass.
6. An Investigation and Report on the Pomeroy Iron Works at West Stockbridge, Mass., by Theo. E. Schwarz, Boston.

THE DEPARTMENT OF CHEMISTRY exhibits:

Five Theses of the Graduating Class.

1. Anthracene, a Coal-Tar Product, by Charles R. Fletcher, Chelsea, Mass.
2. The Action of Chloride of Sulphur upon Spirits of Turpentine, by Albert H. Low, of Chelsea, Mass., and Charles N. Waite, of Medford, Mass.
3. The Action of Tungstic Acid upon Gelatin, by W. P. Atwood, Lowell, Mass.
4. A Practical estimation of the Value of Tanning Materials, together with Points on Tanning, by Wm. E. Nickerson, Somerville, Mass.
5. The Determination of Oxygen in Organic Bodies, by Charles C. R. Fish, Cambridgeport, Mass.

THE DEPARTMENT OF PHYSICS exhibits:

I. *Experiments.*

1. Estimating Tenths.
14. Spherometer.
72. Polarized Light.

These experiments are selected from a list of two hundred, and are performed by students in classes of twenty or thirty.

The apparatus is simple, inexpensive, and not easily injured.

II. *Work done by students.*

1. Curves showing the results of the above experiments.

When two nearly coinciding are given, one is obtained by calculation, the other by actual measurement.

2. Photographs taken by students.
3. Simple Truss Bridge, built by students.
4. Arch Bridge, planned, built, tested and reported upon by E. Holbrook, student.
5. Draw-bridge, planned, built, tested and reported by C. D. Austin and W. T. Blunt, students.

III. *Novelties and Inventions.*

1. Polarimeter, to measure the amount of polarization in a beam of light. Invented by E. C. Pickering.
2. Simple apparatus for drawing Lissajous' curves. Invented by E. C. Pickering.
3. Wind Vane. Invented by W. H. Pickering, student.

4. Micrometer Level, and Mountain Stadia, to determine the height and distance of a distant mountain. Invented by E. C. Pickering.

5. Balance, in which the object to be weighed and the weights are successively placed in the same scale. Invented by E. C. Pickering.

6. Dividing Engine. A cheap and accurate instrument for constructing scales of equal parts. Invented by E. C. Pickering.

7. Plane Table. Invented by E. C. Pickering.

8. Cosine Galvanometer.

9. Simple Galvanometer.

10. Phonautograph Curves, drawn by C. F. Morey, student.

11. Daylight Photometer, made by Charles H. Williams, student.

12. Results of experiments made by students on saving heat by different ways of covering steam pipes.

13. Resistance Coils, made and adjusted by students.

14. Published Memoirs, by students.

15. Text Books.

16. Examination Papers on Lectures.

IV. *Three Theses by the Graduating Class.*

1. The Atomic Theory as applied to Gases, with some Experiments on the Viscosity of Air, by Silas W. Holman, Framingham, Mass.
2. New Experiments in Sound, by William W. Jaques, of Newburyport, Mass.
3. On the Mean Specific Gravity of the Earth, by J. B. Henck, Jr., of Brookline, Mass.

THE DEPARTMENT OF NATURAL HISTORY exhibits:

Two Theses by the Graduating Class.

1. Geology of Eastern Massachusetts, with a Map, by W. O. Crosby, Georgetown, Col.
2. Catalogue of the Alcidæ contained in the Museum of the Boston Society of Natural History, with a Review and proposed Classification of the Family, by W. B. Barrows, of Reading, Mass.

THE DEPARTMENT OF SCIENCE AND LITERATURE exhibits:

Three Theses by the Graduating Class.

1. The Kingdom of Italy, by W. E. Davis, of San Francisco, Cal.
2. The Times of Edward the Third, by Charles H. Heustis of Hyde Park, Mass.
3. The British Provinces of Australia, by Charles A. Sawyer, of Chicago, Ill.

THE DEPARTMENT OF PHILOSOPHY exhibits:

Two Theses by the Graduating Class.

1. Kant's Æsthetic: A Re-statement of it, with some Critical Queries, by David W. Phipps, Boston, Mass.
2. Historieal and Logical Relations between Fichte and Kant, by R. C. Ware, Marblehead, Mass.

THE LOWELL SCHOOL OF PRACTICAL DESIGN exhibits seventy-seven designs in thirty-seven frames, the work of its male pupils. The work of the female pupils is exhibited in the Women's Pavilion.

CATALOGUE OF MATERIAL

COLLECTED AT

THE CENTENNIAL EXHIBITION OF 1876.

CONTENTS.

DEPARTMENT I. — EDUCATION AND SCIENCE.

Class.

1. Books and Pamphlets for the General Library.
2. " " " " Department of Civil Engineering.
3. " " " " " Mechanical Engineering
4. " " " " " Mining Engineerlng.
5. " " " " " Architecture.
5½. " " " " " Physics.
6. Articles constructed from Wood and Iron for purposes of Instruction.

DEPARTMENT II. — AGRICULTURE.

FOREST PRODUCTS.

7. Timber and useful Woods.

TEXTILE SUBSTANCES OF ANIMAL OR VEGETABLE ORIGIN.

8. Wool, washed and unwashed.
9. Hair, Bristles, &c.
10. Silk in the cocoon and reeled.
11. Cotton on the stem, in the ball, and ginned; also Cotton and Fibre Seeds.

AGRICULTURAL PRODUCTS.

12. Cereals, (Wheat, Rye, Oats, &c.,) with their products.
13. Plants used for Food other than Cereals, (Peas, Beans, &c.)
14. Nuts.
15. Fleshy Fruits, (Dates, Apricots, &c.)
16. Thein Plants, (Tea, Coffee, Cocoa, &c.)
17. Sacharine Seeds and substances.
18. Aromatics, (Anise, Dill, &c.)

19. Oleagineous Seeds, (Flax, Rape, Dill, &c.)
20. Forage Plants, (Clover, Hay, &c.)
21. Gums and Resins.
22. Medicinal Plants.
23. Miscellaneous Seeds and Plants.

DEPARTMENT III.—MINING AND METALLURGY.

MINERALS, ORES, BUILDING STONES AND MINING PRODUCTS.

24. Mineral Combustibles, (Coals, &c.)
25. Clays, Kaolin, Silex, &c., Earths, and Refractory Stones for Furnace Linings.
26. Limes, Cements, both raw and burned, accompanied by specimens of the crude rock or material used. Also Artificial Stone, Concrete, &c.
27. Iron Specimens in the Pig and Rolled Bar.
28. Collection of Ores and Associated Minerals.

METALLURGICAL PRODUCTS.

29. Lead and Silver, (the result of extractive processes).

DEPARTMENT IV.—MANUFACTURES.

YARNS AND WOVEN GOODS.

30. Cotton Sheeting and Shirting, plain and twilled.
31. Coarse Fabrics of Bark, Grass, &c.
32. Woolen and Mixed Fabrics, Yarns, &c.

METALLIC PRODUCTS.

33. Telegraphic Wires and Specimens of the Insulating Materials in both the Crude and Manufactured states.
34. Specimens of Nails, Tacks, &c.
35. Files and Hardware.

CHEMICAL PRODUCTS, CERAMICS, POTTERY, ETC.

36. Bricks, Drain Tiles, &c.
37. Fire Clay Goods, (Crucibles, Pots, &c.)
38. Tiles, plain, enamelled and encaustic; also for pavements, roofing, &c.
39. Porcelain and Pottery.

DEPARTMENT I.

CLASS 1. BOOKS AND PAMPHLETS FOR THE GENERAL LIBRARY.

169. Abernethy, Alonzo. School Laws of Iowa.
72. American Museum, N. Y. 1st Annual Report, 1870.
73. " " " 2d " " 1871.
74. " " " 3d and 4th " 1872.
75. " " " 5th and 6th " 1874.
76. " " " 7th " 1875.
71. American Museum, N. Y., ceremonies at laying of corner stone, 1874.
5. Argentine Republic. Centennial Catalogue of the Argentine Section.
14. Austria. Katalog. der Osterreichischen Abtheilung.
135. Bankers Building (Centennial Grounds). Report of Opening of Building.
136. Barcena, Mariano. Certain Mexican Meteors.
24. " " The Rocks known as Mexican Onyx, (2 copies.)
11. Belgique. Catalogue des produits industriels et des Œuvres D'Art, (4 copies).
7. Belgium. Catalogue des Œuvres D'Art, (3 copies).
118. Belgium. Construction et Ameublement de Batiments D'Ecole.
94. Bitterlin, Paul et Fils. Catalogue of Publications.
204. Boston College Catalogue, 1874–75.
155. School of Modern Languages, Boston. Report.
107. Brazil. Agricultural Industries for Emigrants.
35. " Archivos do Museu Nacional.
101. " Catalogo da Exposiçao Nacional em 1875.
36. " Descripçao topographica do Mappa da provincia de Santa Catharina.
19. " Estudos sobre A Quarta Exposiçao Nacional de 1875.
102. " Relatorio sobre a pretendida enxertia da canna de assucar, 1876.
34. " Revista de Horticultura.
33. " Subsidies to the formation of the physical map of Brazil.
21. " Supplement No. 1 to Brazilian Catalogue.
27. " Special Catalogue of the Brazilian Section.
98. " The Empire at the Universal Exhibition, 1876.
99. " " " (German)
100. " " " (French)
13. " The Maté of Parana.
20. " Trabalhos Historicos Geographicos. E. Hydrographicos.
198. Brewers' Industrial Exhibition 1876. Essays on the Malt Liquor Question.
53. Buist & Co., Phila. Catalogue and Garden Manual.
124. Canada. Catalogue of Educational Exhibit.
87. " Catalogue of Exhibitors.
134. " Council of Arts and Manufactures.
79. " Descriptive catalogue of Economic minerals.
59. " Educational Institutions of the Province of Ontario.
57. " Information for intending emigrants.
64. " Province of Ontario, Annual Report of Commissioners on Agriculture and Arts.
208. " Rapport sur le service de l'Asile d'Alienes de Quebec.
125. " Report of Fruit Grower's Association of Ontario.

91. Canada. Report of the Select Committee on Immigration and Colonization.
92. " Report of the Surveyor General of Dominion Lands.
209. Carlisle, Henry C. Sixth annual report of the Trade, Commerce, Railroads of Indianapolis.
2. Catalogue du cercle de la librarie de l'imprimerie.
137. Charlestown. Report of the Sect. of Infant-schools.
226. Charpentier, —. Catalogue de la Bibleothèque-Charpentier.
152. Chauncy Hall School. Catalogue.
31. Chicago. Course of study for Public Schools.
97. " Twenty-first Annual Report of Board of Education.
170. Chili. Catalogue of Centennial Exhibit.
171. " " " " in Portuguese.
17. China. Catalogue of the Chinese Section.
189. Christern, F. W. Catalogue of Standard French Books.
220. Clarke Institution. Teaching the Deaf by Articulation.
150. " J. L. History of the Massachusetts Insurance Department.
126. Coldwater. Address to the State Public School.
115. College of Holy Cross. Historical Sketch.
232. Cone, Wm. R. (et. als.). Anniversary of the Retreat for the Insane at Hartford, Connecticut.
143. Connecticut. Hospital for the Insane. Report of the Board of Trustees.
233. " " " Tenth Annual Report.
231. " State Reform School. Twenty-Fourth Annual Report, 1876.
23. Creswell, F. Australia. List of Seeds.
200. Crosby, W. O. Report on the Geological Map of Massachusetts.
139. Deer Island, (Boston Harbor). Pauper Boys School.
190. Delagrave, Ch. Extrait du Catalogue Général de la Librairie.
186. Delahaye, V. Adrien et Cie. Catalogue des Livres de Fonds.
9. Denmark. Catalogue of Danish Section.
144. Doulton Stone-ware and Lambeth Faience.
225. Ducroro, —. Catalogue of the Ducroro Library.
210. Dufferin, Lord. "Canada the place for the Emigrant."
80. Dumaine, J. Catalogue de la Librarie Militaire.
179. Empire Transportation Co. Statements, etc.
236. Fialho, Aufriso. "Dom Pedro II, Emperor of Brazil."
84. Foote, A. E. Catalogue of Minerals.
39. France. Catalogue des ouvrages de Géographie et de Topographie de Institut Géographique de Paris.
85. Germany. Catalogue of Exhibit of Chemical Industry.
4. " Catalogue of German Section.
123. " Der Buchhandel und Die Graphischen künste Deutschlands.
175. Giovanni Bouceneelli e Figli. The Manufacture of Mosaics.
208. Grafton High School. Catalogue. 1875–6.
Great Britain. Catalogue of British Section.
86. Guillaumin et Cie. Catalogue.
172. Hawaii. Statistics and Information.
47. " Hawaiian Guide Book.
153. Heard, J. C. Report of the Russian Ministry of War.
221. Henderson, Howard, A. M. Exhibit of Kentucky's Educational System and Institutions.

222. Henry, James P. Resources of the State of Arkansas.
191. Hetzel, J. & Co. Catalogue of Publications.
141. Highland Military Academy. Report.
118. Holidaysburg Seminary. Catalogue of Officers and Students.
215. Holland. The Artisan's School in Rotterdam.
164. Howard, B. Frank Annual Report of the Pork Packing of the West.
206. Illinois Industrial University. Catalogue, 1875–6.
51. " Report of the Railroad and Warehouse Commission, 1875.
63. " School Report, 1873–4.
37. India. Descriptive Catalogue of Indian Section.
111. Indiana. Agricultural Report, 1875.
112. " Geological Survey, 1875. Cox, E. T.
107. " Institute for the Blind. Twentieth Annual Report.
108. " New school law, and report of the Supt. of Public Instruction, 1872–3–4.
109. " Twentieth report of the Supt. of Public Instruction.
110. " Twenty-second " " " "
89. " Twenty-third " " " " 1875.
45. Iowa. State Facts.
18. Italy. Catalogo degli Expositori Italiani.
48. Japan. Catalogue of Imperial University of Tokio.
80. " Catalogue of Japanese Section.
49. " Report of the Minister of Education, 1873.
65. Kansas. Agricultural Report, 1875. (2 copies.)
82. Kuhn, B. The Farmers Friend.
228. Laboulaye, M. Ch. Dictionnaire des Arts et Manufactures et de l'Agriculture.
120. Lafayette College. Catalogue of Officers and Students.
140. Lasell Seminary. History and Description.
117. Lehigh University. Catalogue of Officers and Students.
223. Lévy Nuchel. Catalogue of Publications.
229. Lovues, Henri. Catalogue de la Librairie Renouard.
184. Lowell, Mass. Fiftieth Annual Report of School Committee, 1875.
106. Maryland. Report of the Commissioners of Fisheries.
159. Massachusetts. Catalogue of Educational Exhibit.
219. " Catalogue of Exhibit of Industrial Drawing and Modelling.
158. " Educational Institutions, 1876.
147. " Report of the Supt. of the School for Feeble Minded Youth.
148. " State Board of Health. First Annual Report.
149. " State Library. Report of the Librarian.
160. " Tenth Annual Report on Inland Fisheries.
227. Massen, G. Catalogue général de l'Académie de Médecine.
56. Maury, M. F. Resources of West Virginia.
127. Mayhew, Ira. Statement and Exhibit of Business College work.
52. Meme, Alfred & Sons. Catalogue of Publications.
67. Meteorological Observatory, N. Y. Report of the Director, 1871.
69. " " " " " " 1872.
68. " " " " " " 1873.
70. " " " " " " 1874–5.
213. Meyer, Heiur – Ad. – "Ivory."
32. Mexico. Catalogue de la colleccion de Productos Naturales Indigenas.
10. " " of Mexican Section. (3 copies.)

128. Michigan. Chart and Key of the Educational System.
129. " Sketches of its Resources and Industries.
130. " Historical Sketch of the University of Michigan.
131. " Calendar " " " "
132. " Second Annual Report of the Board of Control of the State Public Schools.
133. " Catalogue of Centennial Exhibit.
42. State Catalogue.
156. Montreal. Report of Fruit Committee of Agricultural and Horticultural Society, 1876.
217. Moore, J. G. & Co. Creosoting by the Bethel Process.
193. Moreira, Nicolau, J., M. D. Brazilian Coffee.
192. " " " " Note on Brazilian Vegetable Fibres.
188. Morel et Cie. Catalogue de la Librairie Morel.
58. Mount Holyoke Seminary. Historical Sketch.
181. Munday, E. H. The Proof Sheet.
29. Netherlands. Catalogue of Booksellers Association.
1. " Collection of the Treasury Department.
78. " " " " "
66. " Elementary and Middle Class Instruction.
55. New Brunswick. Catalogue and Report on the Woods and Minerals.
196. New Jersey. Catalogue of the Centennial Exhibit of the Geological Survey.
6. New South Wales. Catalogue of Centennial Exhibit.
211. " " " Its Progress and Resources.
212. " " " Mineral map and general statistics.
161. " " " " " " " "
40. Newspapers. Catalogue of American Newspapers, 1876.
151. Newton. Report of Public Schools.
28. Norway. Norwegian Special Catalogue.
201. Nowell, Edwin C. Paper on the Local Industries of Tasmania.
12. Pennsylvania. Catalogue of Educational Exhibit.
122. " Common School Laws.
50. " School Report, 1875.
104. " " " "
8. Perthes, Justus. Verlags Catalog.
214. Peter, Robert, M. D. Hemp Culture in Kentucky.
121. Philadelphia Institution for the Feeble Minded. Catalogue of Exhibit.
26. Philippine Islands. Catálogo General. (3 copies.)
180. " " Catalogue of Forestal products exhibited at the Centennial Exhibition, 1876.
230. Pickering, T. R. Connecticut at the International Exhibition.
138. Pittsfield High School. Statistics, etc.
224. Plou, E. & Cie. Catalogue of Publications.
168. Polytechnic Review. May 10th, 1876.
178. Proctor, J. R. General account of the Commonwealth of Kentucky.
216. Quebec Lunatic Asylum. Report of the Superintendent, 1875.
81. Randolph, Chas. Eighteenth report of the Trade and Commerce of Chicago.
163. Rensselaer. Polytechnic Institute. Annual Register, 1876.
62. " " " Publications. Troy, N. Y.
218. Russell, E. Harlow. State Normal School at Worcester, Mass.

154. Russia. Catalogue of Exhibit of Fossils.
16. " Catalogue of Mining Department of the Ministry of Crown Domains.
3. " Catalogue of Russian Section. (2 copies.)
46. " Catalogue of School Apparatus, etc. Pedagogic Museum.
194. Saldanah da Gama, José, Ph.D. Notes on Textile Plants of Brazil.
195. " " " Products of the Brazilian Forests. Catalogue.
15. Schröder, J. Catalogue and price list of Schröder's Models.
96. Scribner, Armstrong & Co. Catalogue of Educational Publications.
105. Sève, Edaourd. Le Chili tel qu'il est.
197. Shaler, N. S. General Account of the Commonwealth of Kentucky.
88. Shantz, J. Y. Relation d'un voyage a Manitoba.
54. Smart, James H. Indiana Schools and the men who have worked in them.
205. " " Public Instruction in Indiana. Twenty-third Annual Report.
157. Smith College. Report.
199. " Walter. Circular of the Massachusetts Normal Art School.
119. Soldiers Orphans. Annual Report of Pennsylvania Superintendent.
77. South Australia. Its history, resources, etc. Wm. Harcens.
90. Spence, Thomas. Manitoba and the North-west of the Dominion.
162. Sullivan, Sir Ed. Bart. Protection to Native Industry.
83. Sweden. Catalogue of Exhibit by Motala Iron and Steel Works.
88. " Exhibition of Geological Survey.
145. " Hammers Museum. Synopsis.
60. " Swedish Catalogue. Part 1st.
185. Switzerland. Bericht der Erdgenössischen Polytechnischen Schule in Zürich.
41. " Catalogue of Swiss Section.
177. " Report of Artisan's School in St. Gall.
183. " Report of Swiss Unions of Young Merchants, 1876.
142. Tennessee. Its Agricultural and Mineral Wealth.
167. Thompson, Chas. O. Report of the Worcester Free Institution.
182. Trow, Jas. A Trip to Manitoba.
146. Tunis. Règlement des études à la grande Mosquée de Tunis.
234. University of Michigan. Calendar, 1876–6.
165. University of Pennsylvania. Catalogue and Announcement. 1874–5.
166. " " " " 1875–6.
174. " " " " 1876–77.
114. " " Publications by the Medical Department.
61. U. S. Naval Observatory. Reports of Foreign Societies on awarding medals to American Arctic Explorers.
108. Vausant, I. L. The Royal Road to Wealth.
43. Victoria, Australia. Catalogue of Exhibit.
187. Villars, Gauthier. Catalogue des Livres de Fonds, 1876.
116. Warren Street Chapel. Thirty-Eighth Annual Report.
173 Wharton, Joseph. National Self Protection.
235. Wickersham, J. P. The Pennsylvania School Journal. Aug. 1876.
93. Willmett, T. Northern Queensland Directory.
95. Wisconsin. Catalogue and Sketches.
44. " State Report and Catalogue.
202. Wootten, J. E. The Philadelphia and Reading Rail Road.
22. W. Virginia. Catalogue of State Exhibit.

CLASS 2. CIVIL ENGINEERING.

67. American Bridge Co. Album of Designs.
43. Boston. Seventh Annual Report of the Railroad Commissioners.
22. Brazil. Map of the General Railroads and Telegraph lines in Brazil.
23. " " " Provincial Railroads.
24. " " " " " Province of St. Pauls.
26. " Topographical Map of the Province of St. Pauls.
25. " General Map of the Empire.
42. " Railroads of the Province of St. Pauls.
64. Clarke Reeves & Co. Centennial Catalogue and Publications.
2. " " " Photograph of Chain Bridge over Potomac River.
3. " " " " Biddeford Bridge over Saco River. Eastern Railroad.
4. " " " " Trumansburgh Viaduct, Geneva & Ithica Railroad.
38. Davis, Rear Admiral Chas. H. Interoceanic Communication between Atlantic and Pacific Oceans.
39. " " " " Same as preceding, with Maps.
44. Deutschlands. Der Buchhandel und die graphischen künste, auf der wellansselllung zu Philadelphia, 1876.
47. France. Description of the Models, Charts and Drawings relating to the works of the "Ponts et Chaussées" and the Mines.
48. " Same as preceding. (In French.)
49. " Historical and Statistical Studies upon the means of communication in France.
45. Heller & Brightly, Philadelphia. Remarks on Engineer's Surveying Instruments.
62. Holyoke, Mass. City Water Power and Industries.
34. Keystone Bridge Co. Description of Raritan Swing Bridge.
35. " " " Illustrated Circular of Long Span Bridges.
36. " " " Illustrated Albums.
5. Keystone Bridge Co. Photographs. Three views (side, end, and top) of Collowhill Street Bridge over Schuylkill River at Philadelphia.
6. " " " Collowhill Street Bridge (side view).
7. " " " Terre Haute & Indianapolis Railroad Bridge over Wabash River at Terre Haute, Ind.
8. " " " Ohio River Bridge, Parkersburg, West Virginia, Baltimore and Ohio R.R. (end view).
9. " " " " " (side view).
10. " " " Illinois and St. Louis Bridge (finished structure).
11. " " " " " end span (in process of erection).
12. " " Illinois & St. Louis Bridge; all spans (in process of erection).
13. " " " " " Two spans " "
14. " " " " " All spans " "
15. " " Blanks for specifications of Bridge.

16. Keystone Bridge Co. Photographs Ohio River Bridge, Cincinnati Southern Railway. Five sheets of designs.
17. " " " J. L. Piper's Improved Centre for Wrought-iron Turntables.
18. " " " J. L. Piper's Patent Hollow Wrought-iron Columns.
19. " " " Wrought-iron Highway Bridge.
20. " " " " Railway Bridge.
21. " " " Details for wrought-iron Bridge over Mississippi River at Rock Island.
68. Kneffel & Esser. Catalogue of Draughting Instruments.
46. Lyman ———. Description of Lyman's Trigonometer and Universal Draughting Instrument.
66. Mexico. History of the Railway wealth of Mexico.
61. Netherlands. Eckstein, Charles. New method for reproducing Maps and Drawings.
50. Netherlands. Photo-Lithographs. Bridge over the Hollandsch Diep.
51. " " Reclamation of Haarlemmermeer.
52. " " Pneumatic Foundation of the Railway Bridge before the Madse at Rotterdam.
53. " " Bridge at Bommel.
54. " " New Channel from Rotterdam to the North Sea.
55. " " Steel Swing Bridge at Dordrecht.
56. " " A. Lifting-bridge over the Linge. B. Swing-bridge over the North Holland Canal.
57. " " Canal from Amsterdam to the North Sea.
58. " " Bridge at Hurlenburg.
59. " " A. Dam across the Sloe. B. " " Schelde.
60. " Sketch of the Public Works.
33. " View of the Harbor of Flushing.
41. Norman, V. Report on the Design and Construction of a Military Bridge Equipage, 1876.
37. Phoenixville Bridge Co. Clarke, Reeves & Co. Supplement to Album of Designs.
37a. " " Illustrated Album of Designs.
65. Roebling, John A. & Sons. Catalogue and Price-list of Wire Rope.
63. Switzerland. Atlas uber die entwicklung von Industrie und Handel, der Schweiz.
29. " R. Lurzinger, Topographer at Berne. One Map Section Grono.
30. " Wurster, Randegger, & Co. School Atlas.
31. " " " " "
32. " North-East Railroad Co. Album of Road and Stations ——Designs.
1. U. S. Navy. Catalogue of Centennial Exhibit.
40. U. S. Naval Observatory. Instruments and Publications, 1845—1876.

CLASS 3. MECHANICAL ENGINEERING.

19. Arbey, Fd. Illustrated Catalogue of Wood-working Machinery.
49. Aveling & Porter. Road Locomotives, &c. Illustrated pamphlet.
17. Avery, John G., Worcester, Mass. Catalogue of Thread and Twine Machinery.
45. Bough & Sons. Bough's Sectional Mills. Illustrated pamphlet.

81. Botelho de Mayalhaes, Benjamin Constant. Theora das Quantidades Negativas.
41. Buckeye Engine Co. Illustrated circular.
11. Butterworth, H. W. & Sons. Photographs of Drying Machines and Improved Stuffing-boxes.
23. Douglass Manufacturing Co. Descriptive Price-list of Mechanics' Tools.
8 & 36. Eaton, Cole & Burnham. Illustrated catalogue of Steam and Gas-fitters' Supplies.
21. Empire Threshing Machine Co. Descriptive circular.
34. Ferris & Miles. Steam Hammers and Machine Tools.
12. Fitchburg Machine Co. Twelve photographs of Improved Machinery.
47. Ganguillet & Kutter. Hydraulics. Motion of Water in Canals and Rivers.
33. Greenlee Brothers & Co. Descriptive catalogue of Wood-working Machinery.
30. Hampson, Whitehill & Co. "Engines and Boilers."
32. Harrison, Edward. Standard Flouring Mills. Illustrated pamphlet.
37. Hoops & Townsend. Bolts and Screws. Descriptive catalogue and price-list.
9. " " Photographs of Bolts, Screws, &c.
39. Hotchkiss, A. S. The Tower Clocks made by Seth Thomas & Co.
35. Howe & Co. Howe's Improved Scales. Illustrated pamphlet.
6. Kirkaldy. Experimental inquiry into the properties of Faversta Steel.
51. Krupp, Fried., Essen, Germany. Cast-steel and Iron. Descriptive publications.
38. Leffell, James. Improved double Turbine Water-wheel.
43. Lyall, J. & W. Lyall's Positive Motioned Loom.
42. Mast, P. P. & Co. Agricultural Machinery.
13. Mirrbes, Tait & Watson. Photograph of Sugar Mill.
18. Mitchell, J. E. Catalogue of Grindstones and Fixtures.
22. National Fire Alarm Co. Description of Apparatus.
15. Northampton Emery Wheel Co., Leeds, Mass. Catalogue and price-list.
44. Noye, John T. & Sons. Portable Flouring and Grist Mills.
3. Nystrom. New treatise on Steam Engineering.
2. " Elements of Mechanics.
27. Otis Brothers, Yonkers, N. Y. Descriptive pamphlets of Otis Elevators and Hoisting Machinery.
16. Peace, Cox & Co. Steam and Gas Fitters Tools. Catalogue and price-list.
25. Perkins, A. M. & Son. London Heating Apparatus. Descriptive pamphlet.
26. Philadelphia Burring Machine Works. Descriptive pamphlet.
28. Porter, Bell & Co. Light Locomotives. Illustrated description.
24. Pratt & Whitney Co. Descriptive catalogue.
48. Rodney, Hunt & Co. Hunt's Double-acting Turbine Water-wheel. Descriptive circular.
1. Russia. Description of the Scientific Appliances in the Imperial Technical School at Moscow.
50. Shapley & Wells. "The Shapley Engine."
20. Siemen & Co. Description of Regenerative Gas Furnace.
29. Smith, James & Co. Manufacturers Supplies. Illustrated catalogue.
40. South Bend Iron Works. Description of the Works at South Bend, Indiana.
5. Sweden. The state of the Iron Manufacture.
4. Switzerland. Illustrated description of the large Water-works at Bellegrade.
46. Utica Steam Gauge Co. Descriptive circular.
14. Wetherell, Robert & Co. Photograph of Engine Regulator.
7. Yale Lock Manufacturing Co. Illustrated catalogue.

CLASS 4. MINING ENGINEERING.

6. Actien-Gesellschaft fur Anolin-Fabrikation; coal tar products and analine colors.
4. Akerman, Rich. State of the Iron Manufacture in Sweden at the beginning of 1876.
1. Analysen von Durchschnittsproben des Zur Hemrichshütte bei Au an der sieg producirteu Prima spiegeleisens Morke.
5. Boyer, Fredr. & Co. Department of Analine Colors.
2. Krupp, Fried. The Cast-steel and Iron Works at Essen, Germany.
7. Moore, J. G. & Co. "Creosoting by Bethell Process."
8. New South Wales. "Mines and Mineral Statistics."
10. Pennsylvania Steel Co. Catalogue and Album.
9. Sawyer, Fredr. E. "The Coal Trade."
3. Whitewell, —. Illustrated Paper on Whitewell's Patent Fire Brick Stoves.

CLASS 5. ARCHITECTURE.

1. Mott, J. L. & Co. Catalogue of Ornamental Designs.
4. Spain. Conservatory of Arts at Madrid. Perspective Drawings by Evening Classes.
5. " " " " Geometric Drawings.
6. " " " " Human Figure and Ornamental Drawing.
7. " " " " Young Ladies Class.
8. " " " " Water Color Drawing.
3. Switzerland. Kantonsrathhaus herausgegeben durch die Bandirection des Kantons. Bern, 1876.
2. Switzerland. Neue Entbindnuysanstalt herausgegeben durch die Banderection des Kantons. Bern, 1876.

CLASS 5½. PHYSICS.

4. Coston, J. Description of Coston's Telegraphic Night Signals.
3. Juvet, L. P. Glen Falls, N. Y. Photograph of New Time Globe.
2. Western Electric Manufacturing Co., Chicago. Catalogue and price-list.
1. " " " Samples of Insulated Telegraphic Wire.

CLASS 6. ARTICLES CONSTRUCTED FROM WOOD AND IRON FOR PURPOSES OF INSTRUCTION.

From the Imperial Technical School at St. Petersburg, Russia. Department of Industrial Art.

Course No. I. Six pieces of cast iron finished with the file by students, showing the course of instruction in the art of filing.

Course No. II. Nineteen pieces of wrought iron forgings showing the course of instruction in the art of forging.

Course No. III. Seventeen pieces of wrought iron showing the course of instruction in the art of turning.

From the Artisans' School at Rotterdam, Holland.

Complete drawings of the workshops for boys from twelve to fifteen years of age.

The crosshead, governor, connecting rod and valve rod for an upright engine.

Two locks, showing instruction given in filing and fitting. Fourteen forgings showing instruction given in the smith's shop.

Two specimens of copper work, including brazing.

One pulley block and one post showing work done in the turning shop.

Fifteen specimens of carpenters' work, including stair building. Three specimens of carving and inlaid work.

Six specimens of painting upon cloth.

DEPARTMENT II. — AGRICULTURE.

CLASS 7. TIMBER AND USEFUL WOODS.

AUSTRALIA.

From the Colony of Queensland.

1. Araucaria Bidwillii, Hook. Bunya Bunya. Diameter, 30 to 48 in.; height, 100 to 220 ft.

2. Araucaria Cunninghamii, Ait. Moreton Bay Pine. Diameter, 36 to 66 in.; height, 150 to 200 ft.

3. Dammara robusta, Moore. Kawrie or Dundathu Pine. Diameter, 36 to 72 in.; height, 80 to 130 ft.

4. Callitris columellaris, F. Muell. Cypress Pine. Diameter, 20 to 30 in.; height, 40 to 60 ft.

5. Callitris verrucosa, R. Br. The Desert Cypress Pine. Diameter, 12 to 24 in.; height, 50 to 70 ft.

6. Callitris Endlicheri, Parl. The Mountain Cypress Pine. Diameter, 9 to 18 in.; height, 40 to 50 ft.

7. Podocarpus elatus, R. Br. She Pine. Diameter, 20 to 36 in.; height, 50 to 80 ft.

8. Casuarina tenuissima, Sieb. River Oak. Diameter, 18 to 22 in.; height, 40 to 70 ft.

9. Casuarina leptoclada, Miq. The Erect She Oak. Diameter, 9 to 15 in.; height, 20 to 30 ft.

10. Casuarina equisetifolia, Forst. Swamp Oak. Diameter, 12 to 20 in.; height, 50 to 70 ft.

11. Casuarina torulosa, Ait. Forest Oak, Beef wood. Diameter, 9 to 15 in.; height, 30 to 35 ft.

12. Casuarina Cunninghamiana, Miq. Fire Oak. Diameter, 6 to 10 in.; height, 20 to 30 ft.

13. Cedrela Toona, Roxb. Red Cedar. Diameter, 24 to 76 in.; height, 100 to 150 ft.

14. Flindersia Australis, R. Br. Flindosa. Diameter, 36 to 48 in.; height, 80 to 100 ft.

15. Flindersia Oxleyana, F. Muell. Light-Yellow Wood. Diameter, 24 to 42 in.; height, 80 to 100 ft.

16. Flindersia Bennettiana, F. Muell. Bogum Bogum. Diameter, 18 to 26 in.; height, 70 to 90 ft.

17. Flindersia maculosa, F. Muell. Spotted Tree of the Colonists. Diameter, 12 to 18 in.; height, 30 to 40 ft.

18. Owenia venosa, F. Muell. Sour Plum. Diameter, 12 to 24 in.; height, 40 to 65 ft.

19. Owenia cerasifera, F. Muell. Sweet Plum. Diameter, 9 to 18 in.; height, 25 to 35 ft.

20. Amoora nitidula, Benth. Diameter, 18 to 30 in.; height, 70 to 90 ft.

21. Synoum glandulosum, A. Juss. Diameter, 15 to 24 in.; height, 35 to 60 ft.

22. Dysoxylon Muelleri, Benth. Pencil Cedar. Diameter, 20 to 35 in.; height, 70 to 90 ft.

23. Melia composita, Willd. Diameter, 15 to 20 in.; height, 50 to 60 ft.

24. Ailanthus imberbiflora, F. Muell. Diameter, 20 to 28 in.; height, 50 to 70 ft.

25. Bosistoa sapindiformis, F. Muell. Diameter, 6 to 12 in.; height, 15 to 20 ft.

26. Citrus australis, Planch. Native Orange. Diameter, 6 to 14 in.

27. Citrus australasica, F. Muell. Native Lime. Diameter, 6 to 10 in.: height, 15 to 20 ft.

28. Atalantia glauca, Hook. The Native Cumquat. Diameter, 2 to 6 in.; height, 8 to 15 ft.

29. Acronychia Baueri, Schott. Diameter, 6 to 12 in.; height, 16 to 24 ft.

30. Acronychia lævis, Forst. Diameter, 15 to 20 in.; height, 30 to 50 ft.

31. Zanthoxylon brachyacanthum, F. Muell. Satin Wood. Diameter, 6 to 9 in.; height, 20 to 30 ft.

32. Geijera parviflora, Lindl. Diameter, 6 to 12 in.; height, 20 to 30 ft.

33. Geijera Muelleri, Benth. Balsam Capivi Tree. Diameter, 12 to 18 in.; height, 40 to 60 ft.

34. Evodia micrococca, F. Muell. Diameter, 6 to 10 in.; height, 20 to 30 ft.

35. Celastrus dispermus, F. Muell. Diameter, 3 to 5 in.; height, 12 to 16 ft.

36. Denhamia pittosporoides, F. Muell. Diameter, 6 to 8 in.; height, 20 to 30 ft.

37. Denhamia obscura, Meisn. Diameter, 3 to 5 in.; height, 12 to 20 ft.

38. Alphitonia excelsa, Reissek. Mountain or Red Ash. Diameter, 18 to 24 in.; height, 45 to 60 ft.

39. Pittosporum rhombifolium, A. Cunn. Diameter, 6 to 12 in.; height, 40 to 55 ft.

40. Pittosporum bicolor, Hook. Diameter, 6 to 21 in.; height, 20 to 40 ft.

41. Pittosporum phillyræoides, D. C. Diameter, 4 to 6 in.; height, 20 to 35 ft.

42. Tarrietia argyrodendron, Benth. Silver Tree. Diameter, 24 to 34 in.; height, 70 to 90 ft.

43. Tarrietia actinodendron, F. Muell. Diameter, 18 to 30 in.; height, 60 to 70 ft.

44. Commersonia echinata, Forst. Diameter, 6 to 12 in.; height, 20 to 30 ft.

45. Cupania xylocarpa, A. Cunn. Diameter, 12 to 24 in.; height, 40 to 60 ft.

46. Cupania serrata, F. Muell. Diameter, 8 to 14 in.; height, 20 to 30 ft.

47. Diploglottis Cunninghamii, Hook. Native Tamarind. Diameter, 12 to 20 in.; height, 40 to 55 ft.

48. Cupania semiglauca, F. Muell. Diameter, 10 to 20 in.; height, 30 to 60 ft.

49. Ratonia pyriformis. Benth. Diameter, 10 to 18 in.; height, 30 to 45 ft.

50. Nephelium tomentosum, F. Muell. Diameter, 10 to 15 in.; height, 30 to 40 ft.

51. Heterodendron oleæfolium, Desf. Diameter, 4 to 10 in.; height, 20 to 30 ft.

52. Heterodendron diversifolium, F. Muell. Diameter, 4 to 6 in.; height, 10 to 15 ft.

53. Harpullia pendula, Planch. Tulip Wood. Diameter, 14 to 24 in.; height, 50 to 60 ft.

54. Dodonæa triquetra, Andr. Hop Bush. Diameter, 3 to 4 in.; height, 10 to 12 ft.

55. Rhus rhodanthema, F. Muell. Dark Yellow Wood, K. Diameter, 18 to 24 in.; height, 50 to 70 ft.

56. Sarcocephalus cordatus, Miq. Leichhardt's Tree. Diameter, 24 to 30 in.; height, 40 to 60 ft.

57. Ixora Pavetta Roxb. Diameter, 2 to 4 in.; height, 8 to 10 ft.

58. Hodgkinsonia ovatiflora, F. Muell. Diameter, 6 to 10 in.; height, 12 to 20 ft.

59. Canthium lucidum, Hook, and Arm. Diameter, 6 to 12 in.; height, 20 to 30 ft.

60. Canthium oleifolium, Hook. Diameter, 4 to 10 in.; height, 25 to 30 ft.

61. Canthium latifolium, F. Muell. Diameter, 8 to 12 in.; height, 25 to 30 ft.

62. Canthium vacciniifolium, F. Muell. Diameter, 2 to 4 in.; height, 6 to 10 ft.

63. Cœlospermum paniculatum, F. Muell. Diameter, 3 to 5 in.; height, 100 to 150 ft.

64. Callistemon lanceolatus, D. C. Bottle-brush Tree. Diameter, 12 to 18 in.; height, 30 to 40 ft.

65. Callistemon salignus, D. C. Broad-leaved Tea Tree. Diameter, 18 to 24 in.; height, 40 to 60 ft.

66. Melaleuca linariifolia, Sm. Diameter, 20 to 24 in.; height, 30 to 40 ft.

67. Melaleuca nodosa, Sm. Tea Tree. Diameter, 10 to 20 in.; height, 30 to 40 ft.

68. Angophora subvelutina, F. Muell. Apple Tree. Diameter, 20 to 26 in.; height, 40 to 60 ft.

69. Eucalyptus pilularis, Sm. Black-butt. Diameter, 24 to 40 in.; height, 60 to 80 ft.

70. Eucalyptus Microcorys, F. Muell. Diameter, 18 to 30 in.; height, 60 to 80 ft.

71. Eucalyptus hemiphloia, F. Muell. Yellow Box. Diameter, 20 to 30 in.; height, 40 to 60 ft.

72. Eucalyptus siderophloia, Benth. Ironbark. Diameter, 20 to 30 in.; height, 60 to 80 ft.

73. Eucalyptus meleanophloia, F. Muell. Silver-leaved Ironbark. Diameter, 18 to 20 in.; height, 30 to 60 ft.

74. Eucalyptus maculata, Hook. Spotted Gum. Diameter, 20 to 30 in.; height, 60 to 80 ft.

75. Eucalyptus saligna, Sm. Grey Gum. Diameter, 24 to 34 in.; height, 60 to 80 ft.

76. Eucalyptus Resinifera, Sm. Red Mahogany. Diameter, 20 to 30 in.; height, 60 to 70 ft.

77. Eucalyptus corymbosa, Sm. Bloodwood. Diameter, 24 to 30 in.; height, 50 to 60 ft.

78. Eucalyptus globulus, Sm. Blue Gum. Diameter, 30 to 48 in.; height, 70 to 90 ft.

79. Eucalyptus tereticornis, Sm. Red Gum. Diameter, 18 to 30 in.; height, 60 to 80 ft.

80. Eucalyptus Stuartiana, F. Muell. Turpentine Tree. Diameter 24 to 36 in.; height, 60 to 80 ft.

81. Eucalyptus fibrosa, F. Muell. Stringy Bark. Diameter, 18 to 24 in.; height, 40 to 60 ft.

82. Eucalyptus tesselaris, F. Muell. Moreton Bay Ash. Diameter, 14 to 24 in.; height, 30 to 60 ft.

83. Myrtus acmenioides, F. Muell. Diameter, 12 to 18 in.; height, 30 to 40 ft.

84. Eugenia Smithii, Poir. Lilly Pillies. Diameter, 12 to 18 in.; height, 30 to 40 ft.

85. Myrtus Hillii, Benth. Scrub Ironwood. Diameter, 6 to 12 in.; height, 20 to 40 ft.

86. Rhodamnia trinervia, Blum. Diameter, 10 to 18 in.; height, 20 to 30 ft.

87. Rhodomyrtus psidioides, Benth. Diameter, 12 to 20 in.; height, 30 to 40 ft.

88. Rhodamnia argentea, Benth. Diameter, 15 to 22 in.; height, 40 to 60 ft.

89. Tristania conferta, R. Br. Box. Diameter, 36 to 50 in.; height, 80 to 100 ft.

90. Grevillea robusta, Cunn. Silky Oak. Diameter, 30 to 40 in.; height, 80 to 100 ft.

91. Macadamia ternifolia, F. Muell, Queensland Nut. Diameter, 30 to 40 in.; height, 30 to 50 ft.

92. Orites excelsa, R. Br. Diameter, 6 to 14 in.; height, 30 to 60 ft.

93. Banksia integrifolia, Linn. Beef Wood. Diameter, 8 to 12 in.; height, 20 to 30 ft.

94. Persoonia lucida, R. Br.; var. latifolia, A. Cunn. Diameter, 3 to 7 in.; height, 10 to 20 ft.

95. Grevillea Hilliana, F. Muell. Diameter, 10 to 18 in.; height, 40 to 60 ft.

96. Exocarpus latifolia, R. Br. Broad-leaved Cherry Tree. Diameter, 6 to 9 in.; height, 12 to 25 ft.

97. Exocarpus cupressiformis, R. Br. Cherry Tree. Diameter, 4 to 8 in.; height, 10 to 16 ft.

98. Santalum lanceolatum, R. Br. Sandal Wood. Diameter, 3 to 6 in.; height, 15 to 25 ft.

99. Eremophila Mitchelli, Benth. Bastard Sandal Wood. Diameter, 6 to 12 in.; height, 20 to 30 ft.

100. Myoporum acuminatum, R. Br.; var. parviflorum, Benth. Diameter, 4 to 6 in.; height, 12 to 15 ft.

101. Avicennia officinalis, Linn. Mangrove. Diameter, 19 to 20 in.; height, 20 to 30 ft.

102. Gmelina Leichhardtii, F. Muell. Beech. Diameter, 24 to 36 in.; height, 80 to 100 ft.

103. Vitex lignum-vitæ, A. Cunn. Shrub Lignum Vitæ. Diameter, 20 to 24 in.; height, 50 to 70 ft.

104. Elæocarpus obovatus, G. Don. Diameter, 12 to 20 in.; height, 30 to 40 ft.

105. Acacia falcata, Willd. Diameter, 6 to 12 in.; height, 20 to 30 ft.

106. Acacia glaucescens, Willd. Diameter, 12 to 18 in.; height, 30 to 35 ft.

107. Same as 8 in a younger stage.

108. Acacia fasciculifera, F. Muell. Diameter, 10 to 16 in.; height, 30 to 40 ft.

109. Acacia salicina, Lindl. Diameter, 6 to 12 in.; height, 30 to 40 ft.

110. Acacia harpophylla, F. Muell. Diameter, 12 to 20 in.; height, 40 to 70 ft.

111. Same as 110 in a younger stage.

112. Acacia excelsa, Benth. Brigalow. Diameter, 20 to 30 in.; height, 50 to 80 ft.

113. Acacia neriifolia, A. Cunn. Diameter, 6 to 12 in.; height, 20 to 30 ft.

114. Acacia doratoxylon, A. Cunn. Diameter, 6 to 12 in.; height, 25 to 35 ft.

115. Acacia pendula, A. Cunn. Weeping Myall. Diameter, 6 to 12 in.; height 20 to 35 ft.

116. Acacia stenophylla, A. Cunn. Ironwood. Diameter, 15 to 24 in.; height, 40 to 60 ft.

117. Acacia leptostachya, Benth. Diameter, 4 to 10 in.; height, 20 to 25 ft.

118. Acacia uncifera, Benth. Diameter, 3 to 5 in.; height, 6 to 10 ft.

119. Acacia decurrens, Willd; Green Wattle. Diameter, 3 to 8 in.; height, 30 to 40 ft.

120. Acacia amblygona, A. Cunn. Diameter, 6 to 10 in.; height, 20 to 25 ft.

121. Acacia decurrens, Willd. var. mollis, Lindl. Silver Wattle. Diameter, 6 to 10 in.; height, 30 to 40 ft.

122. Albizzia thozetiana, F. Muell. Diameter, 12 to 30 in.; height, 40 to 60 ft.
123. Acacia linifolia, Willd. Diameter, 3 to 4 in.; height, 10 to 15 ft.
124. Acacia penninervis, Sieb. Diameter, 2 to 4 in.; height, 6 to 12 ft.
125. Pithecolobium pruinosum, Benth. Diameter, 5 to 12 in.; height, 40 to 50 ft.
126. Hovea acutifolia, A. Cunn. Diameter, 2 to 4 in.; height, 6 to 10 ft.
127. Barklya syringifolia, F. Muell. Diameter, 12 to 18 in.; height, 40 to 60 ft.
128. Cassia Brewsteri, F. Muell. Diameter, 3 to 6 in.; height, 30 to 50 ft.
129. Jacksonia scoparia, R. Br. Dogwood. Diameter, 3 to 8 in.; height, 10 to 15 ft.
130. Marlea vitiensis, Benth. Musk Tree. Diameter, 6 to 12 in.; height, 20 to 30 ft.
131. Olea paniculata, R. Br. Native Olive. Diameter, 18 to 24 in.; height, 50 to 70 ft.
132. Notelæa ovata, R. Br. Dunga Vunga. Diameter, 6 to 12 in.; height, 20 to 30 ft.
133. Notelæa microcarpa, R. Br. Diameter, 9 to 12 in.; height, 30 to 45 ft.
134. Endiandra pubens, Meissn. Diameter, 18 to 24 in.; height, 40 to 70 ft.
135. Tetranthera ferruginea, R. Br. Diameter, 14 to 20 in.; height, 30 to 40 ft.
136. Litsæa dealbata, Nees. Diameter, 18 to 24 in.; height, 40 to 60 ft.
137. Cryptocarya patentinervis, F. Muell. Diameter, 12 to 20 in.; height, 30 to 40 ft.
138. Cargillia australis, R. Br. Diameter, 6 to 12 in.; height, 30 to 40 ft.
139. Mallotus philippinensis, F. Muell. Diameter, 6 to 14 in.; height, 30 to 45 ft.
140. Mallotus nesophilus, F. Muell. Diameter, 12 to 18 in.; height, 35 to 45 ft.
141. Croton insularis, Baill. Cascarilla. Diameter, 8 to 12 in.; height, 30 to 40 ft.
142. Croton Verreauxii, Baill. Diameter, 3 to 5 in.; height, 15 to 20 ft.
143. Petalostigma quadriloculare, F. Muell. Crab Tree. Diameter, 12 to 18 in.; height, 40 to 50 ft.
144. Excæcaria Agallocha, Linn. River Poisonous Tree. Diameter, 6 to 18 in.; height, 20 to 30 ft.
145. Bridelia exaltata, F. Muell. Diameter, 12 to 18 in.; height, 30 to 45 ft.
146. Bradleia australis, R. Br. Diameter, 12 to 18 in.; height, 13 to 50 ft.
147. Daphnandra Micrantha, Benth. Diameter, 18 to 30 in.; height, 60 to 80 ft.
148. Hormogyne cotinifolia, A. DC. Diameter, 6 to 9 in.; height, 20 to 35 ft.
149. Chrysophyllum pruniferum, F. Muell. Diameter, 12 to 20 in.; height, 30 to 70 ft.
150. Celtis phillippinensis, Blanco. Diameter, 4 to 12 in.; height, 20 to 40 ft.
151. Morus calcar-galli, Cunn. Cockspur Thorn.
152. Ceratopetalum apetalum, Don. Coachwood. Diameter, 24 to 36 in.: height, 70 to 90 ft.

CLASS 8. WOOL, WASHED AND UNWASHED.

Nos. 1 to 89 inclusive are specimens of cloths manufactured in the Netherlands and Brazil, and will be found under the head of Manufactures, Department IV, Class 30.

TASMANIA.

90. Work done by Parkhurst's Patent Burring Picker.
91. Merino, weight 11 lbs. before being skirted.
92. Unwashed fleece.
93. " " No. 1, Extra.
94. Medium qual., washed.
95. Unwashed fleece from the Ram "Duke."
96. Commercial fleece, washed.
97. Unwashed fibre, nine inches long.
98. Exhibition by F. Shaw.
99. Fleece, washed.

100. Merino from unwashed fleece.
101. Washed on the sheep.
102. Extra quality washed.
103. Unwashed.
104. Washed by hand. Extra long and fine.
105. Washed. Extra quality.
106. Merino fleece, 1st quality, unwashed.
107. Commercial, washed.
108. Medium quality — washed and unwashed.
109. Merino, extra quality, unwashed.
110. Fleece, unwashed.
111. Merino, as shorn from sheep.
112. Lamb's, extra quality.
113. Fine fleece, washed.
114. Leicester.
115. Medium quality.
116. Fleece, Merino, medium quality, unwashed.
117. Commercial.
118. Merino, medium quality, unwashed.
119. 1st quality, washed in the fleece.
120. Extra quality lamb's wool, washed.
121. Good quality, long fibre.
122. Medium quality, washed.
123. Merino, 1st quality, washed.
124. Merino, unwashed.
125. Medium quality.
126. Extra quality lamb's wool.
127. Fleece, unwashed.
128. Coarse wool, 13 inches long.

AUSTRALIA.

129. Merino, 1st quality, unwashed.

New South Wales.

130. Merino, extra No. 1.
131. Merino, unwashed.
132. No. 1, unwashed.
133. Merino fleece, washed.
134. Merino, 1st quality, unwashed.
135. Merino, washed.
136. Merino, unwashed, extra No. 1.
137. Merino fleece, unwashed.
138. 1st quality.
139. Merino, 2d quality.
140. 1st quality
141. Merino, unwashed.
142. 1st quallty, washed.
143. Merino, washed.
144. Fair Merino.
145. Cotswold.
146. Washed in the fleece.
147. 3d quality, unwashed.
147. Merino fleece, extra quality.
149. Merino, 2d quality
150. Merino fleece, No. 1.
151. Prime quality, unwashed.
152. Medium, washed.
153. Fine Merino, washed.
154. No. 3, unwashed.
155. Merino, 2d quality.
156. Merino, No. 3, fleece.
157. Merino, good quality, unwashed.
158. Lamb's, washed.
159. Medium, unwashed.
160. Merino, extra fine and long.
161. No. 1, washed.
162. Merino, unwashed.
163. Extra quality washed.
164. Merino, washed.
165. Fair quality.
166. Medium quality.
167. Merino, No. 3, washed.
168. No. 1, unwashed.
169. Merino, unwashed.
170. Medium fleece, washed.
171. No. 1, unwashed.
172. Extra fine fleece, washed.
173. Fleece, washed.
174. " "
175. Merino, No. 2, unwashed.
176. Merino fleece, washed.
177. " " "
178. Merino fleece, extra quality, unwashed.
179. Medium quality unwashed.
180. Merino, No. 2, unwashed.
181. Medium quality, unwashed.
182. Fleece No. 1, washed.
183. Medium, washed by hand.
184. Extra Merino, washed by hand.
185. 1st quality, washed by hand.
186. Merino, No. 1, washed.
187. No. 1, Merino, washed.
188. 1st quality Merino, washed.
189. Merino, No. 1, washed.
190. Medium, unwashed.
190*a*. " washed.
190*b*. No. 1, washed.

Victoria.

191. Greasy fleece wool.
192. Hot water worked fleece.
193. Washed on the animal; age when shorn 6 months.
194. From Melbourne.
195. Ewes, washed.
196. Greasy fleece.
197. Merino ewe's fleece.
198. Greasy Lincoln.
199. Merino ewe's, fed on natural pasturage only.
200. Greasy Merino.
201. Wethers, greasy Merino; 12 months' growth.
202. Washed ewe's fleece.
203. Greasy Merino ewe's fleece.
204. Greasy crossbred.
205. "
206. " Merino.
207. Hot water washed.
208. Greasy Leicester.
209. Merino ewe's.
210. Greasy crossbred.
211. " Merino.
212. Washed Merino.
213. Fleece, hot water washed.
214. Merino, wether.
215. Washed fleece.
216. Young ewes, hot water washed.
217. Washed fleece.
218. From Geelong.
219. Greasy Merino.
220. Washed Merino.
221. Greasy Merino.
222. " "
223. Washed Merino ewe's fleece.
224. Greasy fleece.
225. Washed Merino.
226. Greasy fleece.
227. " Merino lamb's.
228. " crossbred.
229. Wool.
230. Greasy Lincoln.
231. " "
232. From Thos. F. Cumming.
233. " "
234. " "
235. " "
236. Washed Merino,
237. Merino lamb's, hot water washed.
238. Greasy Merino.
239. Cheviot ewes.
240. Greasy Merino ewe's.
241. Washed ewe's.
242. " crossbred.
243. Merino.
244. Scoured fleece.
245. Washed Merino lamb's.
246. " "
247. Greasy.
248. " crossbred.
249. Cheviot lamb's.
250. " "
251. " "
251*a*. " "
251*b*. Merino ewe, 12 month's growth.
251c. Ewe lamb, 12 month's growth.

Queensland.

252. Merino.
253. "
254. "
255. "
256. "
257. "
258. "
259. " 2d quality unwashed.
260. " " " washed by hand.
261. " " " unwashed.

TASMANIA.

262. Merino, 1st quality.
263. Known as No. 74.
264. Merino, unwashed.
265. Fleece from Merino ram.
266. Merino, unwashed.
267. " "
268. " "
269. from the ram "Melhimus."
270. from ewe.
271.

AFRICA.

Cape of Good Hope.

272. Wool known as Tides.
273. Merino unwashed.
274. " fleece.
275. "
276. Known as No. 95.
277. " fleece.
278. " unwashed.
279. " in the natural grease.
280. Wool.

281. Angora hair.
282.
283. Wool, scoured.
284. " 95.
285. " Merino.

RUSSIA.

286. Merino, washed.
287. " "
288. " "
289. " "
290. " unwashed.
291.
292.
293. Merino, unwashed.
294. " washed.
295. " "
296. " unwashed.
297. Goat's hair.

TURKEY.

298. Angora hair.
299. Goat's hair.
300. Camel's hair from Bagdad.
301. " " " Aleppo.
302. " " " Dardanelles.
303. Goat's " " Sivas.

CANADA.

304. Hamilton wool, 27 cts. per lb.
305. Cotswold fleece.
306. Wool.
307. "
308. "
308*a*. "
309. "
310. " John Harvey & Co.
310*a*. " " " 30 cts. per lb.

BRAZIL.

311. Wool.
312. "

CLASS 9. HAIR, BRISTLES, ETC.

BRAZIL.

313. Hair.
314. Hair.

TURKEY.

315. Camel's hair.
316. " " Esine.
317. " " Bagdad.
318. Bagdad, coarse wool, washed.
319. Konieh, Hair or coarse wool.
320. Erzeroum, Camel's hair.
321. Castamanni, Hair.
322. "Duvet de chien."
323. Adana, Camel's hair, very long.
324. Smyrna, Wool.
325. " "
326. Konieh, "
327. Wool.
328. Coarse wool.
329. Castamanni wool.
330. Bagdad, "
331. Prérézé, " unwashed.
332. Tripoli, woolen yarn.
333. Broussl, thread, black silk.

CLASS 10. SILK IN THE COCOON AND REELED.

TURKEY.

334. Samos, Silk, raw.
335. " " "
336. " " "
337. " " "
339. Silk, cocoons, Antakir.
340. "
341. " La Canée.
342. " Yanina.
343. " "
344. " Monastir.
345. Silk, Monastir.
346. " Salonique.
347. " Government.
348. " Smyrna.
349. " Konieh.
350. " "
351. " Salonique.
352. " "
353. " "
354. " La Canée.
355. " Yanina.

356. Silk, Yanina.
357. " "
358. " "
359. " Bigha.
360. " "
361. " Yaniña.
362. " Diarbekir.
363. " Yskeep.
364. " Valoma.
365. " "
366. " Konieh.
367. " Yanina.
368. " Samos.

AUSTRALIA, QUEENSLAND.

369. Silk. Cocoons, Japanese worm.
370. " European "

SPAIN.

371. Silk.
372. "
373*a*. "

BRAZIL.

374. Silk.
375. " Raw.

EGYPT.

375*a*. Vegetable fibres, Silk of the Gamphocarples fruit.

CLASS 11. COTTON ON THE STEM, IN THE BALL, AND GINNED; ALSO COTTON AND FIBRE SEEDS.

EGYPT.

376. Cotton.
377. "
378. "
379. "
380. "
381. "
382. "
383. " Aschmuni.
384. " "
385. " "
386. " "
387. " "
388. " "
389. " "
390. " "
391. " "
392. " "
393. " "
394. " "
395. " "
396. " "
397. " "
398. " "
399. " "
400. " Mako.
401. " "
402. " "
403. " Hindi.
404. " Sciubra.
405. Cotton and cotton seed, Monteray.
06. " " " " Indian.
407. Cotton seed, Indian.
408. Cotton seed. Ash Muni.
409. " " America.
410. " "
411. " "
412. " "

SOUTH AMERICA, BRAZIL.

413. Paina of Chorisa speciosa.
414. " " "
414*a*. " " "
415. Cotton.
416. " S. Paulo.
417. " Pernambuco.
418. " "
419. " Matto Grosso.
420. " Porahyba.
421. " Bemposta.
422. " "
423. " "
424. " Moranhuo.
425. " Ceara.
426. " Rocha Leao.
427. " Rio Grandi del Nort.
428. "
429. " Cotton seed, S. Paulo.
430. " " " Bemposta.

MEXICO.

431. Cotton, Algodon, Pachuea.
432. " " Cuantha.
433. " " Morelia.
433*a*. " " "

434. Cotton, Algodon, Guerrero Rio Coahuila.
435. " " San Luis Potosi.
436. " " Saltillo.
437. " " Oaxaca.
437*a*. " " "
438. " " Pachuca.
438*a*. " " "
439. " " Campech.
440. " " Merida.
441. " " Ceiba.
441*a*. " " "
441*b*. " " "

RUSSIA.

442. Cotton seed, Ag. Museum Univ. of Domains.
443. " " " " "
444. " " " " "
445. " " " " "
446. " " " " "
447. " " Sea Islands.
448. " Buttons, Ag. Museum Univ. of Domains.
449. " Samarkand.
450. " Kokan.
451. "
452. " Ag. Museum Univ. of Domains.
453. " Kokan.
454. " Katta Uranchy.
455. " Buchana.
456. " Sea Island, Samarkand.
457. " 1st qual. "
458. "

TURKEY.

459. Cotton.
460. "
461. " Bagdad.
462. " Kennyek.
463. " Monastir.
464. " Bagdad.
465. " Yanina.
466. " Dalatmas.
467. Maidos cotton.
468. Polatanas cotton in bolls.
469. Aleppo " "
470. Yanina "
471. Diarbekir cotton.
472. Cotton.

INDIA. NETHERLANDS COLONIES.

473. Cotton with seed.
474. Vegetable fibres.
475. " "
476. " "

FIJI ISLANDS.

477. South Sea Island Cotton.
478. " " " "

AUSTRALIA, QUEENSLAND.

479. Cotton.
480. "
481. " No. 2.
482. "
483. " No. 1.
484. " "
485. " No. 2.

KANSAS.

486. Cotton.

CHINA.

487. Cotton seed, Hupeh Prov.
488. " " Shantung Prov. value at Chefoo $0.08 pe sample.
489. " " Chehkiang Prov. for making oil. Valued at Ningpo $3.00 per pecul.
490. " White.
491. " Yellow.

EGYPT.

492. Jute fibre seed.
493. Aralia papyrifera.
494. Broussouetia.
494*a*. Ramieh Fibre.

CLASS 12. CEREALS (WHEAT, RYE, OATS, ETC.), WITH THEIR PRODUCTS.

CHINA.

495. Wheat, Shantung Prov.
496. Wheat, Tamsui Dist.
497. " Kiangse.

498. Wheat, Newchwang.
499. " Shantung Prov.

CAPE OF GOOD HOPE.

500. Wheat, 1st qual.
501. " "

CANADA.

502. Wheat, Highgates.
503. " Manitoba.
504. " Pr. Ed. Island.
505. " Manitoba.
506. " Ontario.
507. " Spring.
508. " Nova Scotia, Lost Nation.
509. " Nova Scotia Spring.

CHICAGO BOARD OF TRADE.

510. Wheat, white winter.
511. " Spring.
512. " N. W. Spring.
513. " Red winter.
514. " N. W. Spring.
515. " " "
516. " Spring.
517. " Rejected spring.

DENMARK.

518. Wheat, Champion.
519. " Hallet's white.
520. " Hickling's prolific.
521. " Kolbcheode.
522. " Spalting's prolific.
523. " Manchester.
524. " Falveria.
525. " Kentish red.
526. " Full measure.

EGYPT.

527. Wheat, 1st qual.
528. " Gharbijeh.
529. "

FRANCE.

530. Wheat, Golden drop.
531. " Algeria.
532. " Clear.
533. " Brown.
534. " Algeria.
535. "
536. " de Hernon.
537. "
538. "
539. Wheat, Kissengland.
540. "
541. "
542 to 570e. A collection of samples of Wheat from Victoria.

NETHERLANDS COLONIES. GUELDERLAND.

571. Wheat, red bunch.
572. " smooth eared.
573. " red.
574. " smooth eared.
575. " red Swedish.
576. " rugged eared.
577. " " "
578. " tough.
579. "
580. " white.
581. " " Polish.
582. " " Bunch.

MEXICO.

583. Wheat, Frigo de Guanajuato.

NORWAY.

584. Wheat, Spring heavy.
585. " Winter, 1875, "
586. " " "

RUSSIA.

587. Wheat, Kazan, Model farm.
588. " " " "
589. " Pleghin.
590. " "
591. " "
592. " " 1st qual.
593. " " extra.
594. " "
595. " Bell.
596. " Nostilz.
597. " "
598. " Maltzoff extra.
599. " Tablotzky Dessetovsky.
600. " Tablotzky "
601. " Dookhinoff.
602. " Petrovsky.
603. " Obralnoff.
604. " Odessa Exchange Com.
605. " " " "
606. " " " "
607. " " " "
608. " " " "

609. Wheat, Dyokhinoff.
610. " Ermoloff.
611. " Kobzareff.
612. " Levchin.
613. " Plechanoff, extra qual.
614. " Firsoff, " "
615. " "
616. " Ookhin.
617. " Shotiloff.
618. " Stichensky.
619. " Vassiltchikoff.
620. " "
621. " Vickberg.
622. " "

SPAIN.

628. Wheat, Frigo.
624. " "
625. " "
626. " " Alaza.
627. " " Alonso.
628. " " "
629. " " "
630. " " "
631. " " Caudeal.
632. " " "
633. " " Esquivel, No. 1.
634. " " "
635. " " Macolo.
636. " " Var Neyro.
637. " " Kylebery.
638. " " Pichi.
639. " " Raspeblanco.
640. " " " 2d qual.
641. Black Wheat, Sarria (Provencia de Lugo).
642. Wheat, Frigo, Ucgrillo im Varipa.
643. " Frigo, Ucgrillo im Varipa.
644. " Frigo, Verdial.

SWEDEN.

645. Wheat, Kolbchoede.
646. " Clear.
647. " 2d qual.

TASMANIA.

648. Wheat, Archer, W. D. Longford.
648*a*. " " " "
649. " Red Tuscan, Creswell, C. F.
650. " Golden Crop, Creswell, C. F.
651. " Purple straw, Creswell, C. F.
652. Wheat, Red Lamas, Creswell, C. F.
653. " Farmer's Friend, Cresswell, C. F.
654. " Goldsmith.
655. " —— Gibson, W.
656. " Winter Braemar Velvet, Hogarth, D., Launcestown.
657. " Lamont's Prolific, Kemp, G. A., Upper Bagdad, 1875.
658. " Armstrug's Prolific, Kemp, G. A., Upper Bagdad, 1875.

TUNIS.

659. Wheat, medium quality.

TURKEY.

661. Wheat, from Adana (fair).
662. " " Andunoples.
663. " " An Gora.
664. " " Candie (crile).
665. " " " (criss).
666. " " La Canée.
667. " " " "
668. " " Cahil.
669. " " Diarbekir, extra long and heavy.
670. " " Diarbekir, extra long and heavy.
671. " " Dardanelles, 1st quality.
672. " " Dardanelles, 2d quality.
673. " " Erzeroum, 2d quality,
674. " " Kouoo.
675. " " Monastir.
676. " " "
677. " " "
678. " " Sivas, extra quality.
679. " " Smyrna.
680. " " Yanina.
681. " " " 1st qual.
682. " " " 2d qual.

MEXICO.

684. Wheat, Frigo.
685. " " de Puebla.
686. " " "

NETHERLANDS COLONIES. ZEELAND.

687. Wheat, Canada.
688. " Chiddaw.
689. " Hallett's white Pedigree.

690. Wheat, Hunter's white.
691. " Macklenburgh.
692. " Rough chaffed, Essex.
693. " Rivet's Bearded.
694. " Summer.
695. " Tannton Dean.
696. " Walchurern.
697. " White square-headed.
698. " Zeeland.
699. " Brazil.
700. " "
700*a*. " "

CANADA.

701. Rye, Nova Scotia.
702. " Barley oats.
703. " Fall rye.

CHICAGO.

704. Rye, Chicago Board of Trade, No. 1.
705. " " " " No. 2.
706. " " " "Rejected.

DENMARK.

707. Rye, Campen.
708. " Eldenaur Bastard.
709. " Graf Valdersdorff.
710. " Jerusalenes.
711. " Swedish Land.
712. " Vaja Land.

FRANCE.

713. Rye, Single, 36 Hectolitres de Sigle.

GUELDERLAND.

714. Rye, Great Rije.
715. " Zeeland Rije.

NORWAY.

716. Rye, Summer.
717. " Winter.
718. " "
719. " " 1875.

RUSSIA.

720. Rye.
721. " Bell.
722. " Dookhinoff.
723. " Kazan Model Farm.
724. " " " "
725. " Novossiltseff.
726. " "
727. " "
728. Rye, Odessa Exchange Committee.
729. " Vassiltchikoff.
730. " Vickburg.
731. " "
732. "

SWEDEN.

733. Rye, Extra quality.
734. " " Host Rag.
735. " 1st quality.
736. " 2d "
737. " 3d "
738. " early common, No. 11.
739. " early.
740. " hardy.
741. " hulled.
742. " long eared.

TURKEY.

743. Rye, Cus Kun.
744. " Monastir.

ZEALAND.

745. Rye.
746. "
747. " New Giant.
748. " Probster.

CHINA.

749. Millet, Newchwang.
750. " Shantung Prov., value at Chefoo 7 cts. per sample 6338.
751. " Manchooria, fr'm Newchwang 6333.
752. " Shantung Prov., value at Chefoo, 4 to 7 cts. per sample 6336.
753. " Shantung Prov., value at Chefoo, 4 to 7 cts. per sample 6338.
754. " Shantung Prov., value at Chefoo, 4 to 7 cts. per sample 6339.
755. " Shantung Prov., red six cts. per sample 6335.
756. " Kiangsi Prov., value at Ku Kiang $1.16 to $1.54 per pecul 6345.
757. " Kiangsi Prov., value at Chefoo, 3 cts. per sample 6354.

758. Millet, Prov. of Hupeh, used for food and sowing. Value at Hankow $6.00 per pecul 6511.

UNITED STATES.

759. Millet, Delaware.

FRANCE.

760. Millet, Crefle Rouge.

RUSSIA.

761. Millet, Manyuska Model Farm.
762. " Odessa Exch'nge Committee.

TURKEY.

763. Millet, Diarbekir, large.
764. " Cahif.
765. " Yanina.

ZEELAND.

766. Millet, in the ear.

NETHERLANDS COLONIES.

767*a*. Variety of Bird seed.

CHINA.

767. Basil seed, Shantung Province.

AUSTRALIA.

768. Millet, Victoria.
769. Barley, "
770. " English, from Mayston, Vic., 56½ lbs. per bushel.
771. " Malt from Melbourne.
772. " " 59¼ lbs. per bushel.
773. " " from Richmond, 58½ per bushel.
774. " " St. Arnand, 56 lbs. per bushel.
775. " Campbell's creek, 58½ lbs. lbs. per bushel.
776. " " from Melbourne.

UNITED STATES.

777. Barley. California malt fr'm Bergner and Eugel, Philadelphia.

CANADA.

778. Barley from Canada.

PHILADELPHIA.

779. Barley. Refuse from Bergner & Eugel, used for feed.

BRAZIL.

780. Barley.
781. "

CANADA.

782. Barley, Nova Scotia, four rowed.
783. " Nova Scotia.
784. " Manitoba.
785. " Ontario two rowed.
786. " " six "
787. " Toronto.

CHICAGO.

788. Barley, Board of Trade No. 1.
789. " Board of Trade No. 2.
790. " Board of Trade No. 3.
791. " Board of Trade Rejected.

CHINA.

792. Barley, Pearl, Prov. of Hupeh, 6329. Value at Hankow, $3.00 per pecul.
793. " Prov. of Hupeh. Value at Hankow, $1.00 per pecul, 6325.
794. " Kiangsi Prov. Value at Kinkiang 50 cts. per bushel, 6313.
795. " Kiangsi Prov. Value at Chinkiang $2.50 per pecul. 6315.
796. " Manchuria from Newchwang 6363.
797. " Manchuria from Newchwang 6323.
798. " Pearl, Manchuria, from Newchwang, 6327.
799. " Shantung Prov. Value at Ningpo $18.00 per pecul. 4243.
800. " Pearl, Shantung Prov., value at Chefoo 12 cts. per sample 6328.
801. " Suburbs of Ningpo. Value at Ningpo $1.00 per pecul, 6326.

DELAWARE.

802. Barley, Chevaloir.
803. " Potter's.
804. " Carter's prolific.

DENMARK.

805. Barley, Riis.
806. " Great Bluih.
807. " Long specked six rows.
808. " Kalina.
809. " Yorkshire.

EGYPT.

810. Barley, Upper Egypt.

FRANCE.

810*a*. Barley.
811. "
812. " No. 1.
813. " Malt.
814. " "
815 " "

NETHERLANDS COLONIES.

816. Barley, Guelderland.
817. " Guelderland, summer.
818. " Guelderland, winter.
818*a*. " Guelderland.
819. " Guelderland.

NORWAY.

820. Barley, Six rows.
821. " Supposed four rows,

RUSSIA.

822. Barley, Bell.
823. " Deughink,
824. " Korf,
825. " Nostitz,
826. " Novassiltseff.
827. " Black, Novassiltseff.
828. " Odessa Exchange Com.
829. " Petrovska Model farm.
830. " Black, Shatiloff.
831. " Vickburg.
832. " "

NORWAY.

833. Barley, Two Rows.
834. " Hulled Hordeum friforcatum.

SPAIN.

835. Barley, Cebanda Negra.
836. " " Caballar.
837. " "
838. " malt, Cebanda.

SWEDEN.

839. Barley, marked No. 15.
840. " " No. 7.
841. Barley, large grained.
842. " Early.
843. " and oats for feed.
844. Malt, No. 1, marked No. 5.
845. " No. 2, " No. 20.

TASMANIA.

845*a*. Barley Malt, Wm. Gracie, Hobart Town.
846. " " John Degraves.

AFRICA.

847. Barley, Tunis.

TURKEY.

848. Barley, 2d quality.
849. " Aleppo.
850. " Anonnoples, 1st qual.
851. " Cahif, "
852. " Konia,
853. " "
854. " La Canée,
855. " Salonique,
856. " Volonia,
857. " Yanina, 1st quality,
858. " " "

EGYPT.

859. Barley, Upper Egypt.

NETHERLANDS COLONIES.

860. Barley. Zeeland Chavalier.
861. " " Gumagen Spring.
862. " " Six Rows First.
863. " " Summer.
864. " " Thump Winter.
865. " " Winter.
866. " " Winter.

CANADA.

867. Buckwheat,
868. " Manitoba,
869. " Nova Scotia,
870. " Silver Hulled.

CHINA.

871. Buckwheat, Kiangsi Prov. Value at Hinkiang $2.10 per pecul, 6320.
872. " Value at Hinkiang $2.10 per pecul, 6320.
873. " Value at Hinkiang $2.10 per pecul, 6320

874. Buckwheat, Kiangsi Prov. Value at Chinkiang $2.67 per pecul 6321.
875. " Manchuria from Newchwang, 6318.

DELAWARE.

876. Buckwheat.

EGYPT.

877. Buckwheat.
878. " Spinach.
879. " Hemp Ketmil.

NETHERLANDS COLONIES.

880. Buckwheat, Guelderland, Gray Bunch.
881. " Guelderland.

RUSSIA.

882. Buckwheat, Grotenfeld.

SPAIN.

883. Buckwheat, Brioa.
884. " Fajol.
885. " "

AUSTRALIA.

886. Oats, Victoria.
887. " " from Buangor, 52½ lbs. per bushel.
888. " " Grown at Hopton, soil heavy clay. Yield, 40 bushels per acre. Wt. 48 lbs. per bushel.
889. " " Short oats, 52½ lbs. per bushel.
890. " " 50½ lbs. per bushel.
891. " " Tartarian oats from Buangor, 47 lbs. per bushel.
892. " " Tartarian oats from Colomski 45 lbs. per bushel.
893. "

BRAZIL.

894. Oats.

CANADA.

895. Oats, Black.
896. " Pr. Ed. Island Bulman Black.
897. " " " Black.

CHICAGO BOARD OF TRADE.

899. Oats, No. 1.
900. " " 2.
901. " Rejected.

DENMARK.

902. Oats, Algier.
903. " Odenbrucher.
904. " Siberian.

DELAWARE.

905. Oats, black Scotch.
906. " Sandy.
907. " Providence.
908. " Scotch potatos.
909. " Beuvisk.

FRANCE.

910. Oats, black.
911. " black, large yield.
912. "
913. " black.
914. " Avoine rouge.
915. " " black.
916. "

GUELDERLAND, NETHERLANDS COLONIES.

917. Oats, Procstein.
918. " big.
919. "
920. " bunch.
921. "

NORWAY.

922. Oats, black.
923. " No. 2.
924. " Potato.
925. " No. 3.
926. "
927. " Kinn Bush.
928. " Mixed barley and oats, 102 Holland lbs.
929.

RUSSIA.

930. Oats, Ermoloff.
931. " Shatiloff.
932. " Odessa Exchange Committee.
933. " Shatiloff.
934. " Vassellchikoff, R. W.
935. " Dookhinoff.
936. " Bell.
937. " Fereoff.
938. " Kazan Model farm.

939. Oats, Novossiltseff.
940. " Dookhinoff.
941. " Kazan Model farm.
942. " Leochin.
943. " Stichinsky.
944. " "

SPAIN.

945. Oats, Avena.
946. " "
947. " "

SWEDEN.

948. Oats, No. 3.
949. " Hulls.
950. " Mixed grain.
951. "
952. "

TASMANIA.

953. Oats, Poland.
954. " Tartarian.
955. " "

TURKEY.

956. Oats, Canée.
957. " Yanina, 1st qual.
958. " "
959. " Kus Kuri.
960. " Bevat.
961. "

ZEELAND, NETHERLANDS COLONIES.

962. Oats, Heavy Groningen.
963. " Frisian.
964. " Winter.
965. " Black Tartarian.
966. " Danish.
967. " Probster.

BRAZIL.

970. Rice, unhulled white.
971. " " yellow marked 1040.
972. " Hulled, extra, marked Maranhou.
973. " Marked Moranhou, 1043.

CHINA.

974. Rice, Black roasted and taken as coffee, South Formosa.
975. " 2d qual., " "
976. " 3d crop.
977. " Tamsui district.
978. "
979. Rice, 2d crop, suburbs of Ningpo.
980. 3d " " "
981. " Tamsui district.
982. " " "
983. " Shangtung Prov.
984. " Unshelled, 2d crop, suburbs of Ningpo.
985. " 1st qual., South Formosa.
986. " Paddy, Kiangsi Prov.
987. " " Tamsui district.
988. " 1st crop unshelled, suburbs of Ningpo.
989. " 3d qual., South Formosa.
990. " " " "
991. " Paddy, Tamsui district.
992. " 2d qual., Kiangsi Prov.
993. " Paddy, Tamsui district
994. " 2d qual., Fukien Prov.
995. " Red, South Formosa.
996. " Tamsui district.
997. " 2d crop unshelled. Suburbs of Ningpo.
998. " 1st qual., Kiangsi Prov.
999. " Paddy, Tamsui district.
1000. " " " "
1001. " Kiangsi Prov.
1002. " " "
1003. " 3d crop unshelled. Suburbs of Ningpo.
1004. " Tamsui.
1005. " unshelled, Prov. of Foochow
1006. " Suburbs of Ningpo.
1007. "

EGYPT.

1008. Rice barley.
1009. " cleaned.
1010. " barley.

MEXICO.

1011. Arroy de Yucatan, unhulled rice.

TURKEY.

1012. Variety of rice.

HAWAIIAN ISLANDS.

1013. Rice, unhulled.
1014. " hulled, No. 1.
1015. " " " Chaleur Plantation.
1016. " " No. 2. " "
1017. " " No. 1. Wiahole Plantation.

INDIA, NETHERLANDS COLONIES.

1018. Rice, on the stalk.
1019. " " " marked 119.
1020. " " " marked 120.
1021. " " " marked 121.
1022. " " " marked 122.
1023. " " " marked 123.
1024. " Shelled, marked 124.
1025. " Red, shelled, marked 125.
1026. " Black, " " 126.
1027. " White, " " 127.
1028. " " " " 128.
1029. " " " " 129.
1030. " " " " 130.
1031. " Unshelled " 131.
1032. " Shelled " 132.

SPAIN.

1037. Rice, Arroz Cilindrad.
1038. " " "
1039. " " "
1040. " " "

MEXICO.

1041. Rice, Arroz de Puebla.

CHINA.

1042. Rice, Shantung Prov. Basil seed.
1043. Maize, Kiangsi Prov.
1044. Corn, Prov. of Hupeh. Value at Hankow $3.00 per pecul. 6330.
1045. " Manchuria from Newchwang, Maize, 6347
1046. " Manchuria from Newchwang, Maize, 6346.
1047. " Suburbs of Ningpo. Value at Ningpo $1.50 per pecul.
1048. " Shangtung Prov. Value at Chefoo 4 cts. per sample. 6348.
1049. " Shantung Prov. Value at Chefoo 4 cts. per sample. 6349.
1050. " Small yellow.

CHICAGO BOARD OF TRADE.

1051. Corn, No. 1.
1052. " " yellow.
1053. " " white.
1054. " No. 2.
1055. " New high mixed.
1056. Corn, new mixed.
1057. " Rejected.

DELAWARE.

1058. Corn, Adams extra.
1059. " Yellow, known as Canada.
1060. " Extra early.
1061. " Tuscarora.
1062. " Early sugar.
1063. " Ground seed.
1064. " White Flint.

EGYPT.

1065. Corn, Naire Maize.
1066. " Pearl "

MEXICO.

1067. Corn, Maize de Yucatan.

SPAIN.

1068. Corn.
1069. " Eucarnado de Francia.
1070. " Maiz perla blanco.
1071. " Maiz perla inferior.
1072. " Maiz amorillo de la perla.

RUSSIA.

1073. Corn, Maize Denyhink red.
1074. " " " yellow.
1075. " Odessa Exchange Com.

TURKEY.

1076. Corn, Andrinoples, 1st qual.
1077. " Canée.
1078. " Catril.
1079. " Dardanelles.
1080. " Hidgar.
1081. " Volonia Maize.
1082. " Yanina.

BRAZIL.

1083. Flour of Mandioca.
1084. " " "
1085. Farinha de "
1086. Scraping of " powdered.
1087. Starch of "
1088. Fecula.
1089. Corn meal.
1090. From corn.
1091. Prepared corn.
1092. Starch.
1093. Tapioca, Escaldad.
1094. Arrow root.
1095. marked 818.

1096. marked 817.
1097.
1098. " 179.
1099. " 816.
1100. " 792.

CHINA.

1101. Wheat flour, Shantung Prov.
1102. Macaroni, " "
1103. Vermicelli, Newchwang.

CANADA.

1104. Oatmeal, Mount Forest.
1105.

GLEN COVE, N. Y.

1106. Duryea's Satin Gloss Starch.
1107. " " " "
1108. " Improved Corn Starch.
1109. " Maizena.

HAWAIIAN ISLANDS.

1110. Tapioca.
1111. Farina.
1112. Arrow root.
1113. " "

OSWEGO, N. Y

1114. Corn-Starch for culinary use.
1115. Blue Starch.
1116. Silver Gloss Starch.
1117. Refined Corn-Starch.
1118–1120. Varieties of starch.

NETHERLANDS.

1121. Flour, Meal, &c.
1122. " " "
1123. " " "
1124. " " "
1125. " " "
1126. " " "
1127. " " "
1128. " " "
1129.

SPAIN.

1130. Afreitas.

SWEDEN.

1131. Nafn-gryn. 2 gauger krossode.
1132. Rag-mjol.
1133. Wheat Bran.
1134. Rag-mjol.
1135. Nafu-gryn.
1136. Hafregryns mjol (affan).
1137.

TURKEY.

1138. Bulbed Selep (a starchy food).

TASMANIA.

1139. Flour from Tasmania.

CLASS 13. PLANTS USED FOR FOOD OTHER THAN CEREALS, (PEAS, BEANS, ETC.).

AUSTRALIA.—VICTORIA.

1140. Beans, long pod; the best yielding variety known; from Geelong.

BRAZIL.

1141. Beans.
1142. " speckled.
1143. " Castor Oil.
1144. " red mixed.
1145. " "
1146. " white flat.
1147. " " common.
1148. " " sweet early.
1149. " light silver "Carana," 1020.
1150. " dark silver, small.
1151. " light gray, 1017.
1152. " " very small.
1153. Beans, yellow.
1154. " yellow, small.
1155. " reddish yellow.
1156. " red, 1004.
1157. " long mixed, 1005.
1158. " brown.
1159. " " small.
1160. " " Parana, 1014.
1161. " brown.
1162. " dark mixed.
1163. " yellowish, 1018.
1164. " reddish, 1007
1165. " large yellow 1018.
1166. " reddish medium.
1167. " horse.
1168. " "
1169. " spider, 1048.
1170. " black, 1009.

1171. Beans, black, medium, 1015.
1172. " " "
1173. " black, small, 1019.
1174. "

CANADA.

1175. Beans, Montreal White Pea.
1176. " Nova Scotia Purple speckled Bush.
1177. " " " Dunclourd Bush.
1178. " " " Yellow-eyed Bush.
1179. " " " Dwarf China Bush.
1180. " " " Pole.
1181. " " " Royal pale.
1182. " " " Fawn.
1183. " " " Robin's egg Bush
1184. " " " Provincial.
1185. " St. Janvier Early Brown.
1186. " Petite Cote H.
1187. " Province Quebec Dwarf Butter.
1188. "
1189. "

CHINA.

1190. Black beans from Formosa.
1191. Large flat green Peas, Kiangsi Province.
1192. Large black Beans, Shantung Province.
1193. Beans, white, suburbs of Ningpo.
1194. " small green, Kiangsi Prov.
1195. " " Shantuug "
1196. " " " Kiangsi "
1197. " " Hupeh "
1198. " " Shantung "
1199. " black, Hupeh Prov.
1200. " small green Newchwang.
1201. " black, Formosa.
1202. " " for rheumatism, Kiangsu.
1203. " white, Shantung Prov.
1204. " yellow, Kiangsi "
1205. " rice, Formosa.
1206. " small black, Shantung Prov.
1207. " white, " "
1208. " black, " "
1209. " yellow, " "
1210. " large black, " "
1211. " " red, " "
1212. Beans, large red, Shantung Prov.
1213. " yellow, Hupeh Prov.
1214. " red, Shantung "
1215. " large, suburbs of Ningpo.
1216. " flat, Kiangsi Prov.
1217. " " " "
1218. " small mixed, Shantung Rrv.
1219. " from Newchwang.
1220. " " Kiangsi Prov.
1221. " " Formosa.
1222. " " Kiangsi Prov.
1223. " name unknown, Kiangsi Prov.
1224. " from Newchwang.
1225. " Kiangsi Prov.
1226. " medicine, Newchwang.
1227. " Chefoo.
1228. " Newchwang.
1229. "
1230. "

DELAWARE.

1231. Beans, Mohawk.

EGYPT.

1232. Beans, large white.
1233. " " round.
1234. " speckled butter.
1235. " red kidney.
1236. " Lubia Doliohos.
1237. "
1238. " from lower Egypt.
1239. " (Castor oil) Ricurus plant.
1240. " from Fayoma.
1241.
1242. " Dolichos Lablab.

FRANCE.

1243. Beans, large white.

NETHERLANDS COLONIES, GUELDERLAND.

1244. Beans, Arab short.
1245. " white short.
1246. " " "
1247. " " French.
1248. " "
1249. " yellow.
1250. " brown.
1251. " yellow, short.
1252. " horse.
1253. " " mixed.
1254. " Pigeon.
1255. " spotted short.
1256. " Fretillery.

1257. Beans, salad short.
1258. " white.
1259. " Mottha.
1260. " spotted French.
1261. " Laden big beans.
1262. "
1263. " Frijol de Puebla.
1264. " " " Yucatan red.
1265. " " " " black.

RUSSIA.

1266. Beans, French, Odessa Exchange Committee.
1267. " French, Odessa Exchange Committee.
1268. " French, Manyska model farm.
1269. " French, Manyska model farm common.
1270. " large flat common.
1271. " sweet French.

SPAIN.

1273. Beans, Judias de Garrofa.
1274. " Habas de Manteca.
1275. " Habas Mumda.
1276. " Judias.
1277. " Jabachas blancas.
1278. " Fosols.
1279. " " Jabes.
1280. " " Renegas.
1281. " Judias Rénegas senoritas.
1282. " Judias pintadas.
1283. " Chinas.
1284. " Fasols Gabachas.
1285. " Jabas.
1286. " Fasols Reneyas dark.
1287. " Frijoles Americanos.
1288. " Habas negras panesquetas.

SWEDEN.

1290. Beans, yellow.
1291. " brown.
1292. " green, large.

TASMANIA.

1293. Beans, horse. C. F. Creswell.

TUNIS.

1294. Beans, white.
1295. " small black spots.
1296. " large, flat.

TURKEY.

1297. Beans, Adana, Castor Oil.
1298. " Aleppo, small.
1299. " Canée, small.
1300. " Konia, white.
1301. " Palamar.

NETHERLANDS COLONIES.

1302. Beans, Zeeland.
1303. " large white.
1304. " giant runners.
1305. " white globe.
1306. "
1307. " small white.
1308. " " "
1309. " white dwarf.
1310. " black Pewet.
1311. " brown "
1312. " large speckled.
1313. " brown "
1314. " large brown.
1315. " Pigeon.

GUELDERLAND.

1316. Beans, great.
1317. " " flat.
1318. " Gronnigen.
1319. " Ruiselaer.
1320. " large, mixed.
1321. " sheep.
1322. " Besilian sheep.
1323. " Thump.
1324. " sugar.
1325. "
1326. "
1327. "

AUSTRALIA, VICTORIA.

1328. Peas, Bellevine new fodder.
1329. " Geelong new fodder.
1330. " Bellevine Prussian Blue, crop of 1876.
1331. " Geelong, 1876, Yorkshire head, delicious.

BRAZIL.

1332. Peas, marked 1080.
1333. " Chicaro Parana.
1334. " white.
1335. " small green.

CANADA.

1336. Peas, white.

1337. Peas, young.
1338. " Beauharions gray.
1339. " Manitoba Field.
1340. "
1341. " " Crown.
1342. " Vandeuil Bean.
1343. " Nova Scotia marrow fat.

CANADA.

1344. Peas, Yeudon split.

CHINA.

1345. Peas, Hupeh. Value at Hankow $2.50 per pecul.
1346. " Wuton. Value at Kiukiang $1.46 per bushel.
1347. " large yellow. Value at Chinkiang $2.67 per pecul.
1348. " Kiangsi, small dried. Value at Chinkiang $2.60 per pecul.
1349. " Pharbitis convolvulus. Value at Ningpo $7 00 per pecul.
1350. " Pharbitis seed. Value at Ningpo $7.00 per pecul.
1351. " Kiangsi Vitexirisea. Value at Ningpo, $8.00 per pecul.

EGYPT.

1352. Peas, chick.
1353. " sugar. Pisum Sativium.
1354. " green crushed.
1355. " from Middle Egypt.
1356. " roasted chick.
1357. " Lupine.
1358. " Vitia Stativa.
1359. " Cyperus Esculentus.

BRAZIL.

1360. Peas.

FRANCE.

1361. Peas, mixed.

NETHERLANDS COLONIES. GUELDERLAND.

1362. Peas, green crown.
1363. " green field.
1364. " " "
1365. " yellow "
1366. " Capucin yellow.
1367. " " brown.
1368. " gray.

NORWAY.

1369.
1370. Peas, gray, early ripe.
1371. Peas, black, for fodder.

RUSSIA.

1372. Peas, Ermoloff.
1373. " Levchin.
1374. " Odessa Exchange Com.
1375. "

SPAIN.

1376. Peas, Melas.
1377. " Attramuces.
1378. " "
1379. " Guijas.
1380. " Titos ó muclas.
1381. " Garbanzoi.
1382. " " not cultivated in U. S.
1383. " quisantes verdes.
1384. " Zeros, (Coresha de 1875.)
1385. " Areponces.
1386. " "
1387. " Galgana.

SWEDEN.

1389. Peas, small white, early.
1390. " white, grown by F. Jacobson.
1391. " green.
1392. " white hvita.
1393. " early green.
1394. " small early green.
1395. " Aker arter (gra).
1396. " black.

TASMANIA.

1397. Peas.
1398. " Field green, Hoodford's, from C. F. Creswell.
1399. " grey, C. F. Creswell.

TUNIS.

1400. Peas, yellow.
1401.

TURKEY.

1402. Peas, Bagdad, early table.
1403. " La Canée, small.
1404. " " "
1405. " Dardanelles, small.
1406. " Konia.
1407. " Smyrna, small.
1408. " Yanina, mixed.
1409. " " "
1410. " " small dark.

NETHERLANDS COLONIES, ZEELAND.

1411. Peas.
1412. " white.
1413. " large blue.
1414. " small blue.
1415. " wrinkled.
1416. " brown.
1417. "

NORWAY.

1418. Tares, Futter Viciar.

RUSSIA.

1419. Tares, Mookhin white.
1420. " " black.
1421. " Kazan Model farm.

SPAIN.

1422. Tares, Leegum.

SWEDEN.

1423. Tares and oats used for feed.

TASMANIA.

1424. Tares, Golden, C. F. Creswell.
1425. "

EGYPT.

1426. Lentils, Gleditshia friatanthos.
1427. " Upper Egypt.
1428. " Bean, upper Egypt.
1429. " Lower "
1430. " Crushed, lower Egypt.
1431. " " " "

RUSSIA.

1432. Lentils, Pearl Deughink.

SPAIN.

1433. Lentils, algarrola.
1434. " Lentejas.
1435. " "

TUNIS.

1436. Lentils.

TURKEY.

1438. Lentils, Adana.
1439. " Kara Hissar.
1440. " Yanina.

RUSSIA.

1441. Carrot, Zapevaloff.
1442. "

FRANCE.

1443. Beet, Betteraves.

RUSSIA.

1444. Beet, Vassiltchikoff.
1445. " Zablotzky Dessetovsky.

SPAIN.

1446. Beet.

NETHERLANDS COLONIES, ZEELAND.

1447. Beet, mangold wurzel.

CHINA.

1448. Onion, Kiangsu Prov. Leek, value at Chinkiang, $25 per pecul.

RUSSIA.

1449. Onion, Zapevaloff.

TUNIS.

1450. Onion.

TURKEY.

1451. Onion, Smyrna.

RUSSIA.

1452. Radish.
1453. " Zapevaloff.

EGYPT.

1454. Turnip, etc., Brassica Aveka.
1455. " Maysus alba.
1456. " " Ravs.

DELAWARE.

1457. Turnip, white flat.

TURKEY.

1458. Turnip, Saxonkhan.

SWEDEN.

1459. Cabbage, etc.

RUSSIA.

1460. Cress, Zapevaloff.
1461. Spinach.
1462. Lettuce, Zapevaloff.

EGYPT.

1463. Lettuce.
1464. Parsley, Apsium petroselimun.
1465. Spinach.

RUSSIA.

1466. French grass, Ermoloff.
1467. " " Kharkoo Model farm.

EGYPT.

1468. Endive.

1469. Hibiscus Esculentus as used for soup.
1470. Hibiscus Esculentus as used for pickles.

CHINA.

1471. Seeds, commercial, in paper.
1472. " Gourd. Kiangsi Prov. Value at Amoy $22 per pecul.

EGYPT.

1473. Seeds, Gourd. Rouora Tavuile.
1474. " " Pava "

CHINA.

1475. Seeds, Pumpkin. Shantung. Value at Chefoo 8 cts. per sample, 3846.
1476. " Pumpkin. Kiangsi. Value at Chinkiang $15.50 per pecul.

EGYPT.

1477. Seeds, Pumpkin. Quara Houpi.
1478. " " " Asfar.

RUSSIA.

1479. Seeds, Pumpkin. Zapevaloff.
1480. " Cucumber. "

EGYPT.

1481. Seeds, Melon. Shammam.

SPAIN.

1482. Seeds, Melon. Penitas de Melon de todo clano.
1483. " " Penitas.

EGYPT.

1484. Seeds, Melon, Water.

CHINA.

1485. Seeds, Melon, Water. Newchwang.
1486. " " " Kiangsi Prov. An aperient. Value at Chinkiang $19.44 per pecul.

TURKEY.

1487. Seeds, Melon, Winter. Aleppo.

CLASS 14. NUTS.

CHINA.

1488. Brown Lotus Nuts.
1489.
1490. " " " Hupeh Prov. Value at Hankow $6.00 per pecul.
1491. White Lotus Nuts.
1492. Salisberean Seed. Value at Chefoo 11 cts. pecul. Hupeh.
1493. White Nuts for food. Value at Hankow $1.50 per pecul.
1494. Hazel Nuts from Newchwang.

RUSSIA.

1495. Chestnuts from Crimea, Swokhin.
1496. " Povudooks, Swokhin.

CHINA.

1497. Chestnuts. Shantung. Value at Chefoo 12 cts. per sample.
1498. Peanuts. Shantung. Value at Chefoo 17 cts. per sample.

EGYPT.

1499 Peanuts.

SPAIN.

1500. Peanuts. Cacahuet, Mani.
1502. Pinones in shell.
1503. " shelled.

BRAZIL.

1504. Sapucaia Nuts.
1505. Almendras Blamadas del Vale, seed imported from Spain.
1506. Almendra Fina.
1507. Walnuts.

SPAIN.

1508. Walnuts.

CHINA.

1509. Nuts. Chêhkiang.
1510. Apricot kernels. Hupeh. Value at Hankow $7.00 per pecul.

RUSSIA.

1511. Succory. Swokhin, to adulterate coffee.

EGYPT.

1512. Hibiscus Esculentus. Chufas.

SPAIN.

1513. Chufas.
1514. "

CLASS 15. FLESHY FRUITS (DATES, APRICOTS, ETC.).

EGYPT.

1515. Ferones Elephantum.

CHINA.

1516. Jujubes, red. Shantung Prov. Value at Chefoo 3 cts. per sample.
1517. " black. Value at Chefoo 4 cts. per sample.

SPAIN.

1518. Walnuts.

EGYPT.

1519. Melia Azedarach.
1520. " "

SPAIN.

1521. Higos blancos o' de cofin.

EGYPT.

1522. Apricot paste.
1523. Preserved dates from the Oasis.
1524. " "
1525. Phœnis Dactylifera Volma.
1526 " " "
1527. " " da guana.
1528. " " gondala.
1529. " " ibriny.
1530. " " shâmi.
1531. " " "
1532. " " yarroutis.
1533. Ceratnia siliqua.

SPAIN.

1534–1537. Castanas.

CLASS 16. THEIN PLANTS, (TEA, COFFEE, COCOA, ETC.).

BRAZIL.

1538–1547. Coffee.
1548. Cofiee, Bahia.
1549. " " mixed.
1550. " Bemposta.
1551. " "
1552. " "
1553. " " Augusto Sovres.
1554. " " " "
1555. " " choice.
1556. " with and without husk.
1557. " Augusto, Sovres.
1558. " Unhulled.
1559. " "
1560. " Brunido Cantagallo.
1561. " Cantagallo.
1562. " "
1563. " Brunido Cantagallo.
1564. " Crogueira da gama.
1565. " Corovellas.
1566. " Cantagallo, Rio de Janerio.
1567. " Dospolpado.
1568. " Dommgos, Rio de Janerio.
1569. " Exhibition Committee, Vienna.
1570. " Exhibition Committee, Rio de Janerio.
1571. " Eucreo.
1572. Cofiee, Fezueda de Triumpho.
1573. " Lavoda.
1574. " Rio de Janerio.
1575. "
1576–1579. Rocha Leao.
1580. " Rodrigeus Jordao.
1581. " Supelped.
1582–1585. San Paulo.
1586. " Vergueiro.
1587. "

HAWAIIAN ISLANDS.

1588. Coffea, Kona.
1589. " "

MEXICO.

1590. Coffee. Café de Colima.
1591. " " de Cordoba.
1592–1595. Coffee. Café de Uruapan.

INDIA, NETHERLANDS COLONIES.

1596–1654. Coffee, Netherlands Catalogue, Nos. 59–116.

RUSSIA.

1655. Coffee. Barley, Sivokhin.
1656. " Acorn, "
1657. " " "

BRAZIL.

1658–1661. Cocoa.
1662. Cocoa. Dipterius odorator.
1663. "
1664. "

EGYPT.

1665. Tamarind husks.
1666. " "
1667. Pongamia glabra.
1668. " "
1669. Acacia niloiica.
1670. Ceratonia Siliqua.

CLASS 17. SACHARINE SEEDS AND SUBSTANCES.

CHINA.

1672. Sorghum, Kiangsi Prov. Value at Chefoo 2 cts. per sample.
1673. " Kiangsi Prov. Value at Kiukiang $1.50 per pecul.
1674. " Heupeh. Value at Hankow $1.50 per pecul.

TUNIS.

1675. A seed resembling sorghum.

AUSTRALIA, QUEENSLAND.

1677–1682. Sugar.

BRAZIL.

1683. Sugar, Ceara.
1684. " "
1685–1697. Sugar, manufactured at Campas Rio de Janerio.
1698–1709. Sugar, manuf., Pernambuco.

CHICAGO BOARD OF TRADE.

1711. Sugar, Beet, 1st product.
1713. " " 3d "

HAWAIIAN ISLANDS.

1714–1727. Sugar.

INDIA. NETHERLANDS COLONIES.

1728–1735. Sugar.

CLASS 18. AROMATICS, (ANISE, DILL, ETC.).

ALGERIA. FRENCH COLONIES.

1737. Hops.

AUSTRALIA, VICTORIA.

1738. Hops, from the aboriginal station Corrandeuk.
1739. " California, from Bergner & Engel Brewers, Phila.
1740. " best Bavarian, from Bergner & Engel, Brewers, Phila.
1741. " New York, from Bergner & Engel, Brewers, Phila.

FRANCE.

1742. Hops. Burgundy.
1743. " Lorraine.
1744. "

RUSSIA.

1746. Hops. Bohemia.
1747. " "

TASMANIA.

1748. Hops, Golden.
1749. " known as No. 49.

SPAIN.

1750. Cauamones.
1751. "

TURKEY.

1752. Anise seed, from Mardis.
1753. " " " Aleppo.
1754. " " " Dardanelles.

SPAIN.

1755. Anise seed.

TUNIS.

1756–1759. Anise seed.

UPPER EGYPT.

1760–1762. Anise seed.

NETHERLANDS COLONIES. ZEELAND.

1763. Caraway.

RUSSIA.

1764. Dill. Zapevaloff.

TUNIS.

1765. Coreanda.

EGYPT.

1766–1768. Coriandrum Sativum.

SPAIN.

1769. Pimente de Naboo.

CHINA.

1770. Clove Tree seed.
1771–1772. Cloves.

INDIA, NETHERLANDS COLONIES.

1773–1775. Pepper, white.
1776–1779. " black.

EGYPT.

1781–1782. Pepper, red, Capsicum annuum.

INDIA. NETHERLANDS COLONIES.

1783. Chile Mulato.
1784–1789. Mace.

CLASS 19. OLEAGINOUS SEEDS, (FLAX, RAPE, DILL, ETC.).

CHINA.

1790. Seed of a plant, Syschuen Prov.

CANADA, NOVA SCOTIA.

1791. Flaxseed.
1792. " Varrennov.

FRANCE.

1793–1794. Flaxseed.

GUELDERLAND.

1795. Flaxseed.
1796. " Crop of 1875. Direct importation from Riga at Rotterdam.
1797. " Crop of 1875. White blossom, Dutch.
1798. Flaxseed.

RUSSIA.

1799. Flaxseed.
1800. " Bessarabian Horticultural School.
1801. " Pskor Statistical Com.
1802. " Haramycheff.
1803. " Kazan Model Farm.
1804. " Obralnoff.
1805. " Odessa Exchange Com.
1806. " Dootehmoff.
1807. " Repuin Princek.
1808. " Oil Press Pskor Statistical Com.
1809. " Pleshanoff.

SPAIN.

1810. Linaza.
1811. Flaxseed.
1812. "

SWEDEN.

1813. Flaxseed.

TASMANIA.

1814. Flaxseed, from C. F. Creswell.

TUNIS.

1815. Flaxseed.

TURKEY.

1816. Flaxseed from Tutours.

ZEELAND.

1817. Flaxseed.

GUELDERLAND.

1818. Lin Meal.

RUSSIA.

1819. Linseed Oil Cake.

CHINA.

1820–1822. Sesamum seed.
1823. Small Pine. "
1824. Mustard "
1825. Sin "
1826. Cabbage "
1827. Castor oil beans.
1828. " " "
1829. Large pine seed.
1830–1833. Sesamum seed.

RUSSIA.

1834. Canary seed.

FRANCE.

1835. Canary seed, from Algeria.

ZEELAND.

1836. Canary seed.

BRAZIL.

1837. Mustard.

ZEELAND.

1838. Yellow mustard.

RUSSIA.

1839. Sunflower seed. Bessarabian Horticultural School.

TURKEY.

1840. Sunflower seed, white, fr'm Aleppo.

SPAIN.

1841. Sunflower seed. Alazor.

EGYPT.

1842. Sunflower seed. Carthamus.
1843. " " "
1844. Pistacia therebintus.
1845. Poppy.
1846. Lactuca Oleifera.
1847. Rape seed.
1848. " "
1849. White Rape.
1850. Sesame.
1852. Mustard.

FRANCE.

1853. Cameline.
1854. Colza seed.

GUELDERLAND.

1855. Rape seed.

RUSSIA.

1856. Rape seed.
1857. " "
1858. Camline seed.
1859. Rape "
1860. " " wild.

SPAIN.

1861. Semilla de madia sativa.

TURKEY.

1862. Oilseed.

TASMANIA.

1863. Rape seed.

ZEELAND.

1864. Winter rape.
1865–1868. Oilseed.

CLASS 20. FORAGE PLANTS, (CLOVER, HAY, ETC.).

DELAWARE.

1869. Red Clover.

NORWAY.

1870. Red Clover.

RUSSIA.

1871. Clover seed.
1872. " "
1873. " " Kazan Model farm.

SWEDEN.

1874. Clover seed.

TASMANIA.

1875. Perennial Red Clover.
1876. White Clover.

RUSSIA.

1877–1880. Timothy seed.
1881. Kazan Model farm.

SWEDEN.

1882. Timothy seed.
1883. " "
1884. Grass seed.

NORWAY.

1885. Mixed grass seed.
1886. Timothy seed.

DELAWARE.

1877. Timothy seed.

TASMANIA.

1888. Italian Rye-grass seed.
1889. Rape grass seed.

EGYPT.

1890. Cress seed.

AUSTRALIA.

1891. Red grass seed.

FRANCE.

1892. Minette.

DELAWARE.

1893. Hungarian grass seed.

RUSSIA.

1894. Lucerne.

CHINA.

1895. Lucerne.

RUSSIA.

1896. German Mohair.
1897. Mohair.

TASMANIA.

1898. Lucerne.

EGYPT.

1899. Melilotus.
1900. "

SPAIN.

1901. Mijo.

SWEDEN.

1902. Klofver-fro.

1903. Mixed Clover.

RUSSIA.

1904. Spurry.
1905. " Kazan Model farm.

CHINA.

1906. Knot Grass.

CLASS 21. GUMS, RESINS, ETC.

BRAZIL.

1907. Acacia angico.

EGYPT.

1908. White gum.

INDIA.

1909–1911. Crude gums.
1912–1915. Refined wax.

MEXICO.

1916. Campeche wax.

NETHERLANDS COLONIES IN INDIA.

1917–1922. Rubber.

BRAZIL.

1923. Rubber.

QUEENSLAND, AUSTRALIA.

1924. Glue.
1925. Prepared strings for musical instruments.

BRAZIL.

1926. Glue.

CLASS 22. MEDICINAL PLANTS.

INDIA.

1927. Medicinal preparations.

CHINA.

1928. Opium, native. Value at Hankow, $340.00 per pecul.
1929. The fruit of a tree, a medicine. $11.50 per pecul.
1930. Rice roasted and prepared as coffee (not ground) to assist digestion.
1931. A tonic and cooling medicine. $11.00 per pecul.
1932. Cassiatora seed for Ophthalmia. $12.00 per pecul.
1933. A stomachic. $7.00 per pecul.
1934. A tonic and astringent. $13.00 per pecul.
1935. Leek seeds for neuralgia. $5.00 per pecul.
1936. Poison. $14.00 per pecul.
1937. A tonic and antirheumatic. $11.50 per pecul.
1938. Caterpillar for bronchial complaint. $11.00 per pecul.
1939. Cyperus esculentus, a stimulant. $9.00 per pecul.
1940. Cassia sophora bud, a tonic and astringent. $6.80 per pecul.
1941. Scrophularia seed, a stimulant. $5.00 per pecul.

EGYPT.

1942. Fraxinus ornus.
1943. Senna.

INDIA. NETHERLANDS COLONIES.

1944–1951. Medicinal.

MEXICO.

1952. Copal de pudra.
1953. Copalchi. Croton pseudo china.
1954. Lengua de Ciervo. Polypodium lanceolatum.
1955. Artèmina Mexicana Estafiata.
1956. Semillas de balsamo. Mysospermum.
1957. Yerba de la Puebla.
1958. Yerba dulce. Lippia dulcis.
1959. Zempoalxochitt. Zagetes Mexicana.
1960. Yerba del Negro. Malva angustifolia.
1961. Te de milpas. Bidens tetragona.
1962. Prodigiosa. Athanaria amara.

1963. Bonplandi.
1964. Yerba del Canae. Gomphrena procumbens.
1965. Gayuba. Arctostaphylos pungens.
1966. Semillas de cominos nerticos. Thapsia asclepium.
1967. Nanchalahua. Erythrea Sticta.
1968. Palo del Muerto. Ipomæa Mumucoides.
1969. Raiz de Yesgos Urtica Mexicana.
1970. Calayuala. Polypodium aureum.
1971. Tripa de Judas. Cissus tiliacea.
1972. Contrayerba. Dorstenia contrayerva.
1973. Crytrina coralodendrum.
1974. Linaloe de Mexico.
1975. Cana festula. Cassia brasiliensis.
1976. Colancapatli. Solidago Montana.
1977. Salvia Beal. Buddleia globosa.
1978. Mispatle. Buddleia verticillata.
1979. Hachinol. Heimia salicifolia.
1980. Cebadilla. Veratrium cevadilla.
1981. Atlanchana. Cuphea lanceolata.
1982. Dictamo Real. Marrubium pseudo dictamus.
1983. Tacopatle. Aristolochia Mexicana.
1984. Peonia Mexicana. Cyperus rotundus.
1985. Ahuehueti. Taxodium distichum.
1986. Jamaica. Hibiscus sabdarifa.
1987. Yerba del Anel. Eupatorium sanctum.
1988. Gengibre Zingiber officinalis.
1989. Crameria pauciflora.
1990. Raiz de Yndio. Aristolochia fœtida.
1991. Fecula del Jatropha edulis.
1992. Acido Pipitzhoie estrado del fixis pipitzahoac.
1993. Tarilla. Senecio vernus.
1994. Gobunadora de Mexico. Zigophilum fabago.
1995. Tepozan. Buddleia Americana.
1996. Capulin. Cerasus capollin.
1997. Té limon. Andropogon citratus.
1998. Picosa. Croton ciliatum glandulosum.
1999. Cedron. Aloysia citriodora.
2000. Arrayan. Myrtus arrayan.
2001. Yerba del Zorrillo. Croton dioicus.
2002. Flor de Sauso. Sambucus Mexicanus.
2003. Contrayerba. Dorstenia Contrayerva.
2004. Codo de Fraile. Fevetia icotli.
2005. Gordolobo del Pais. Gnaphalium canescens.
2006. Cuapinole. Ambar Mexicana.
2007. Valeriana Folucana Collasatelus.
2008. Semillas de Curcas purgans.
2009. Sudda Consuelda. Potentilla multifida.
2010 Goma del mangle. Rizophora.
2011. Yncienso de Mexico.
2012. Goma de Sonora. Mimosa lacifocra.
2013. Recina del schinus molle mejico.
2014. Goma de Mesquita. Inga circinalis.
2015. Pimienta de Tabasco. Myrtus pimenta.
2016. Cortezia de Cuachalalate Rajania.
2017. Semilla de Ticama. Jolichos tuberosus.
2018. Cuayiote. Rhus perniciosa.
2019. Frittos dela Bixa Orellana.
2020. Toloxochitl. Magnolia Mexicana.
2021. Resina del Achras Zapota.
2022. Doradilla, Lycopodium nidiformis.

RUSSIA.

2023. Poppy seed, Manywska Model Farm.

CAPE OF GOOD HOPE.

2024. Prairie Damask leaves.

TASMANIA.

2025. Eucalyptus Globulus or blue gum. Prevents fever where sown.

EGYPT.

2026. Poppies cut for the opium.
2027. Tamarind cakes from Darfoor.
2028. " " " "

CHINA.

2029-2041. Tobacco.
2042. Large leaf tobacco. Port Foochow.
2043. " " " Newchwang.

GUELDERLAND.

2044-2047. Leaf tobacco for wrappers.
2048. Tobacco.
2049. " for snuff.
2050. " for cigar wrappers.

BRAZIL.

2051. Tobacco.

GUELDERLAND.

2052–2063. Tobacco.

BRAZIL.

2064. Tobacco from the Colony of St. Maria.

GUELDERLAND.

2065. Tobacco for wrappers.
2066. " " "

BRAZIL.

2067–2069. Stalks of rice and rye.

CLASS 23. MISCELLANEOUS SEEDS AND PLANTS.

A. *Fibrous Plants.*

RUSSIA.

2070. Fibrous barks.
2071. " "
2072. Bast string for making rope.

BRAZIL.

2073. Fibrous plants.
2074. " barks for making rope.
2075. " , " as used for rope.
2076. Rope samples.
2077. Broom made from fibrous plants.
2078. Fibrous plants.
2079–2082. Barks from trees as used for paper stock.
2083–2084. Colored fibres as used for coarse cloth.
2084*a*–2084*h*. Certain Brazilian fibres.

TURKEY.

2085. Samos Soie.

CHINA.

2087. Coarse fibrous barks.
2088. Fibrous grass. Newchwang.
2089. " " Takow.
2090. " " "
2091. " "
2092. " " Tamsui.
2093. Fibrous plants for making ropes.
2094. Coarse hemp. King Ma.
2095. Fibrous plants for making rope.
2096. " " " " Amoy.

MEXICO.

2097. Fibres of the Agave Sisalina.
2098. " " " "
2099. Sisal hemp, Agave Sisalina.
2100. Fibres of the Maguey Agave.
2101. " Lechuguella Agave.

CHINA.

2102–2103. Fibrous grass for making cloth. Canton.
2104. Majagua.

MEXICO.

2105. Pita fibres of a bromaceous plant.
2106. Fibres of the Maguey Agave Mexicana.
2107. Pita de Lechuguella.

QUEENSLAND.

2108. Sida Ratusa.
2109. Fibres.
2110. "

HAWAIIAN ISLANDS.

2111. Fibrous barks.

RUSSIA AND HOLLAND.

2114. Flax, blue Dutch, hand scutched.
2115. " " " " "
2116. Flax, 1st qual.
2117. " 5th "
2119. "
2120. Tow No. 2.
2121. Flax, blue blossom seed, mill scutched.
2122. " Blue Dutch, Guelderland.
2123. " " " "
2124. " " " Kin of Riga seed.
2125. " " " Grown in Groningen.
2126. " " " hand scutched.
2127. " " " Friesland Prov.
2128. " " " hand scutched.
2129. " " " mill "
2130. " " " white blossom seed Friesland.
2131. Flax, blue blossom seed, mill scutched.

2132–2145. Flax.
2146. Best Friesland flax. Blue Blossom-seed.
2147–2149. Flax.
2150. Best Groningen flax. Blue Blossom, Riga.
2151. 2d qual. flax.
2152. Prime Friesland flax.
2153–2155. 2d quality B flax.
2156. 2d quality flax.
2157. Tow flax.
2158–2161. Flax.
2162–2165. Half combed flax.
2166. A. H. Whishaw & Co. flax.
2167. " " " "
2168. 1st qual. W. flax.
2169. " " flax.
2170. Best Friesland, hand scutched flax.
2171. " " " " "
2172. 1st qual. flax.
2173. 2d " "
2174. White flax, growth of 1875.
2175. " Zeeland flax.
2176. Groningen, mill scutched flax.
2177. 1st qual. flax.
2178. Best Groningen flax.
2179. " " "

TURKEY.

2180. Fibre resembling flax.
2181. " uncombed.
2182. Italian flax, unscutched.
2183. " " scutched.
2184. Fibrous barks.
2185. " "

RUSSIA.

2186. Flax unscutched.
2187. " "
2188. "
2189. Tow.
2190. Flax, 2d qual.

MEXICO.

2191. Certain fibrous barks.
2192. " " "

HAWAIIAN ISLANDS.

2193. Cloak made from grass.
2194–2220. Various fibres.

NEW YORK.

Contributed by H. W. Jones.

2221. Asbestos from Cecil Co., Md.
2222. " Mitchel Co., N. Carolina.
2223. " Felting.
2224. " paper.
2225. " as used for steam packing.
2226. " thread.
2227. " as used for cement felting.
2328. " as used for board, paper and thread.
2229. " from Harford Co., Md.
2230. " for paints, New York.
2231. " from Harford Co., Md.
2232. " used for lining felt, N. Y.
2233. " Italian.
2234. " from Richmond Co., N. Y.
2235. " " Oconee Co., S. C.

B. *Seeds and Barks.*

TURKEY.

2236. Black cherries.
2237. Hawthorn berries for hedge plants.
2238. " "

RUSSIA.

2239. Cedar nuts.

EGYPT.

2240.
2241. Capia fistulata.
2242.
2243. Cassia faliata.
2244.
2245. Goat's Thorn.
2246. red Coreopsis.
2247. yellow "
2248–2250. Dianthus sinensis.
2251. Gomphrena globosa.

BRAZIL.

2252. Marcella.
2253. "

EGYPT.

2254. Forest tree.

SWEDEN.

2255. Tall-fro, pine seed.
2256. Gran-fro.

EGYPT.

2257. Wigella.

CHINA.

2258. Buckthorn kernels.
2259. Sesamum seed.
2260. Thorn seeds, for hedge.
2261. Seeds.

EGYPT.

2262–2266. Gourds.

TURKEY.

2267–2269. Gall nuts.

CHINA.

2270. White nuts.

TURKEY.

2271. Gall nuts.
2272. Yellow berries, for a dye.
2273. Sumac berries.

ZEELAND.

2274. Two years' dried madder root.

GUELDERLAND.

2275. Oak tan. Peeled by steam engine.

CAPE OF GOOD HOPE.

2276. Damask tree.

SPAIN.

2277. Saffron. Pruin.
2278. Alazor.

ZEELAND.

2279. Dried madder.

CAPE OF GOOD HOPE.

2280. Waggon tree.
2281. Leucandendrum No. 2.
2282. Pro-tea Mellifera.
2283. Knotted tree.
2284. Rockwood.

GUELDERLAND.

2285. Oak tan.

NETHERLANDS.

2286. Indigo seed.

CHINA.

2287. Indigo seed.

EGYPT.

2288–2291. Various seeds.

TUNIS.

2292–2294. Various seeds.

EGYPT.

2295. Seeds.
2296. Forest tree seeds.

BRAZIL.

2297. Seeds.
2298. Seeds, marked 1038.

TASMANIA.

2299. Blackwood.

EGYPT.

2300. Seeds.

NETHERLANDS.

2301. Marked No. 265.
2302. " 266.

BRAZIL.

2303. Southern moss.

EGYPT.

2304. Gauve.

MEXICO.

2305. Dye stuff.

TURKEY.

2306. Various seeds.

EGYPT.

2307–2309. Various seeds.

BRAZIL.

2310. Nuts.

CHINA.

2311–2318. Various seeds.

GUELDERLAND.

2319. Oak tree. Peeled by hand.

DEPARTMENT III. — MINING AND METALLURGY.

CLASS 25. CLAYS, KAOLIN, SILEX, EARTHS AND REFRACTORY STONES FOR FURNACE LININGS.

KENTUCKY.

2321. Pea Ridge soil. Taken 18 in. below surface.
2322. J. W. Scott. Taken 1 foot below surface.
2323. Grayson County. Taken 2 feet below surface.
2324. Little Sandy River. Taken 6 in. below surface.
2325. Iron Hill. Taken 18 in. below surface.
2326. Woods in valley of L. S. River. Taken 6 in. below surface.
2327. Virgin soil in open woods.
2328. Old field subsoil.
2329. Old field soil.
2330. Tygert's Creek. Surface soil.
2331. W. Abbot farm. Old field soil.
2332. " " " " subsoil.
2333. V. Calvin farm. Virgin soil.
2334. Iron Hill. Top soil.
2335. Surface soil.
2336. Iron Hills. Top soil.
2337. " " Subsoil 18 in. below surface.
2338. Siliceous grit.
2339. Old field subsoil.
2340. Iron Hills. 18 in. from surface.
2341. W. Abbott farm. 1 foot from surface.
2342. Iron Hills. Top soil.
2343. Grayson County. Red marl.
2344. J. W. Scott. Subsoil.
2345. " " "
2346–2401. Soils from various counties in Kentucky.

QUEENSLAND, AUSTRALIA.

2402–2405. Soil.

AFRICA.

2406–2411. Sand from the Great Desert.
2412. Sable sand.

KENTUCKY.

2413. Various samples of clay.

NEW JERSEY.

2414. Fire bricks for furnace linings, manufactured by A. Hall & Sons, New Jersey.

ENGLAND.

2415. Fire bricks, manufactured by King Brothers, Stourbridge, England.

WISCONSIN.

2416. Fire bricks from B. W. Felthousen, Milwaukee, Wis.

CLASS 26. LIMES, CEMENTS, ETC.

FRANCE.

2417. Portland cement.

RUSSIA.

2418. Riga cement.
2419. Jabe cement.

HOWE'S CAVE, N. Y.

2420–2430. Jars of powdered cement.
2431–2437. Specimens prepared for the testing machine.
2438–2441. Specimens under water two years.
2442–2456. Specimens of the crude rock from various parts of the cave.
2457. Rough stalagmite.
2458. " " broken lengthwise.
2459. Rough stalagmite broken crosswise.
2460. Polished stalagmite.
2461. Rough stalactite from the cave.

FIRE PROOF BUILDING CO., N. Y.

2462–2470. Artificial stones, manufactured for building purposes.

JOSEPH HAMBLET, STAFFORDSHIRE, ENG.

2471–2475. Artificial stones for building purposes.

ROTTERDAM, HOLLAND.

2476. Various specimens of building stones and bricks.
2477. Collections of tiles and sidewalk paving bricks.
2478. Artificial street paving stones.

CLASSES 27, 28.

A. *Ores and Associated Minerals.*

CANADA.

2479–2530. Collections of ores and minerals from various parts of the Dominion.

NEVADA AND CALIFORNIA.

2531–2536. Rich gold and silver ores.

AUSTRALIA, QUEENSLAND.

2537–2545. Native copper, lead, and tin ores.

PENNSYLVANIA.

2546–2549. Rich iron ores.

OHIO.

2550–2555. Specimens of rich native ores.

WEST VIRGINIA.

2556–2606. Specimens of ores and minerals from various parts of the State.

KENTUCKY.

2607–2631. Selected specimens from several counties.

NEW YORK.

2632. Seven specimens of Ferromanganese containing various percents of Manganese collected and furnished by H. Chapman.

2633–2640. Specimens of coal, ore, and flux, used by the Union Iron Co., Buffalo.

B. *Iron Specimens in the Pig and Rolled Bar.*

UNION IRON CO., BUFFALO, N. Y.

2641. Specimens of pig iron.

2642–2698. Specimens of rolled bars, rails and iron for building purposes.

TRENTON CO., TRENTON, N. J.

2698–2734. Specimens of rolled beams and rails.

RUSSIA.

2735. Pig iron.

2736. Specimens of rolled bar.

CLASS 29. LEAD AND SILVER.

BELGIUM.

2737–2783. Specimens of lead and silver, the products obtained by work upon a silver lead ore.

DEPARTMENT IV. — MANUFACTURES.

CLASS 30. COTTON SHEETING AND SHIRTING, PLAIN AND TWILLED.

BRAZIL.

1–16. Plain and twilled heavy cotton cloths.

AMSTERDAM, NETHERLANDS.

Samples of the Reuendoom Steam Spinning and Weaving.

17. White heavy sheeting.
18. " " " with sample of filling.
19. Bleached.
20. Unbleached.

Samples of Theversmusche Steam Spinning and Weaving.

21. Unbleached plain 42 inches wide.
22. Twilled sheeting dressed.
23. Unbleached.

Komuklykeweefcoederen Fabrik, Van C. T. Stark & Co. te Hencelo.

24–28. Cottonnets, Java.

29–45. Prentanieres Sevant.

46–52. Ginghams.

53–88. Tringano sarongs (British India).

89. Coarse heavy sheetings.

CLASS 31. COARSE FABRICS OF BARK, GRASS, ETC.

CHINA.

2784–2927. Specimens of grass cloth of various varieties.

CLASS 32. WOOLEN AND MIXED FABRICS, YARNS, ETC.

TURKEY.

2927–2939. Linen yarns and threads.
2930. Cotton thread.
2931–2933. Woolen yarns.
2934. Specimen of silk.

CLASS 33. TELEGRAPHIC WIRES AND INSULATING MATERIALS.

SIEMENS BROS., LONDON.

2935. Mediterranean cable.
2936. Military cable, braided.
2937. Harvey's Torpedo cable.
2938. Black Sea cable.
2939. Hong Kong-Shanghai-Posiette. Gt. Northern Telegr. Co. Deep Sea cable.
2940. Shore end of 2939.
2941. Platino Brazilera Telegr. Co.'s cable. Shore end.
2942–2958. Sample coils of various insulated wires.
2959–2962. Specimens of crude gutta percha used for insulating wire.
2963–2970. Specimens of gutta percha in various stages of the process of manufacture.
2971–2975. Gutta percha in the finished products.

CLASS 34. SPECIMENS OF NAILS, TACKS, ETC.

BOSTON, MASS.

2976–2982. Samples of Horse shoe nails from Globe Nail Co.
2983. Sample card of nails and tacks from the manufactory of Dunbar, Hobart & Whidden.

CLASS 35. FILES AND HARDWARE.

FRANCE.

2984–3128. Files from the manufactory of Limet Lapareille & Cie.
3129–3148. Horse shoe magnets from the same firm.

PROVIDENCE, R. I.

3149–3207. Files from the Nicholson File Co.

FROM THE WASHINGTON MILLS, ASHLAND, MASS.

3208–3243. Collection of samples of Turkish emery in the rock as found, and in the manufactured state.
3244. Cascade evaporator. Presented by Wm. R. Lafourcade.

CLASS 36. BRICKS, DRAIN TILES, ETC.

NETHERLANDS ROYAL COMMISSION.

3245. Various specimens of building and drain bricks, also samples of drain pipes.

ENGLAND.

3246–3248. Ornamental bricks for building purposes, by Joseph Hamblet, Staffordshire.

NEW JERSEY.

3249. Varieties of bricks, by A. Hall & Sons, Perth, Amboy.

CLASS 37. FIRE CLAY GOODS (CRUCIBLES, POTS, ETC.).

TAUNTON, MASS.

3250–3305. Crucibles and pots from Phœnix M'fg. Co., as follows:

1 Spelter basin.
1 No. 40, the ordinary size, steel crucible.
1 No. 50 Brass crucible.
2 No. 25 " "
2 No. 20 " "
2 No. 18 " "
2 No. 16 " "
2 No. 14 " "
2 No. 12 " "
2 No. 10 " "
2 No. 8 " "
2 No. 7 " "
2 No. 6 " "
2 No. 5 Brass crucible.
2 No. 4 " "
2 No. 3 " "
2 No. 2 " "
2 No. 1 " "
3 Jeweller's, special.

All of the sizes from No. 1 to 14 are used by jewellers for melting silver, etc.

2 No. 1 Covers.
1 No. 40 Steel cover.
2 No. 4 Dips, used by Reed & Barton.
2 No. 3 " " " U. S. Assay Office.
4 No. 2 " " " " " "
2 No. 1 " " " " " "
2 Stirrers " " " " "
2 Muzzles used by Bessemer steel works.
2 Stoppers " " " " "

CLASS 38. TILES, PLAIN AND ENCAUSTIC, ETC.

LUXEMBOURG.

3306–3312. Specimens of plain floor tiles.

NETHERLANDS.

3313. Various specimens of plain and ornamental floor tiles.
3314. Specimens of roofing tiles.
3315. " " sidewalk paving tiles.

PHILADELPHIA.

3316–3322. Enamelled and encaustic tiles, presented by Sharpless & Watts.

NEW YORK.

3323–3334. Plain and ornamental floor tiles, presented by the Fire Proof Building Co.

CLASS 39. PORCELAIN AND POTTERY.

NEW JERSEY.

3335. Various samples of earthern ware, presented by A. Hall & Sons, Perth Amboy, N. J.
3336–3337. Danish Terra Cotta.

PHILADELPHIA.

3338. Ornamental vase from British Museum, London, presented by Galloway & Graff.
3339. Vase, imitation of Danish ware, from Galloway & Graff.

CLASS 24. MINERAL COMBUSTIBLES, (COALS, ETC.).

WEST VIRGINIA.

3340–3374. Coals from various parts of the State.

PENNSYLVANIA.

3375–3380. Coals from various coal fields.

MEXICO.

3381. Rich gas coal.

AFRICA.

3382–3383. Soft coal from Orange Free State.

AUSTRALIA.

3384–3385. Queensland coal.

BRAZIL.

3386–3398. Various coals.

CANADA.

3399–3400. Pictou coal, Nova Scotia.

KENTUCKY.

3401–3418. Coals from different parts of the State.

INDIANA.

3419. Samples of various coals collected and presented by the State Commission.

ENGLAND.

3420. Pressed coal dust from Birchgrove Colliery.

SWEDEN.

3421–3425. Samples of coke and peat.

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Jasper, Gustavus A.	"
Jenks, Lewis E.	"
Kehew, John	"
Kneeland, Samuel	"

Lamson, Chas. D. . Boston.
Langley, H. P. . . "
Lanza, Gaetano . . "
Lawrence, A. A. . "
Lee, Francis L. . . "
Lee, Thomas J. . . "
Leuchars, R. B. . . "
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Lewis, Wm. K. . . Boston.
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Little, John M. . . "
Lothrop, Sam'l K. . "
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Lowell, John . . . "
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Page, W. H. . . . Boston.
Parsons, Wm. . . "
Paul, J. F. . . . . "
Peabody, O. W. . . "
Perry, O. H. . . . "
Philbrick, Edward S. "
Philbrick, John D. . "
Pickering, E. C. . . "
Pickering, H. W. . "
Pope, Edward E. . "
Prang, Louis . . . "
Putnam, J. P. . . . "

Rice, Alexander H. . Boston.
Richards, R. H. . . "
Ritchie, E. S. . . . Brookline.
Robbins, James M. . Milton.
Robinson, J. R. . . Boston.
Rotch, Benj. S. . . "
Ruggles, John . . "
Runkle, John D. . Brookline.
Russell, LeBaron . Boston.

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Sawyer, Timothy T. Charlestown.
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Sherwin, Thos. . . Dedham.
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Smith, Chauncy . . Cambridge.
Sprague, Chas. J. . Boston.
Stevens, Benj. F. . "
Sturgis, John H. . "
Sullivan, Richard . "

Thompson, Wm. H. "
Tufts, John W. . . "
Tuxbury, Geo. W. . "

Upham, J. B. . . "
Urbino, S. R. . . . "

Ware, Chas. E. . . "
Ware, Wm. R. . . "
Warren, Cyrus M. . Brookline.
Warren, Geo. W. . Boston.
Warren, Joseph H. . "
Warren, Sam'l D. . "
Waters, C. H. . . . Clinton.
Watson, R. S. . . Milton.
Watson, Wm. . . Boston.
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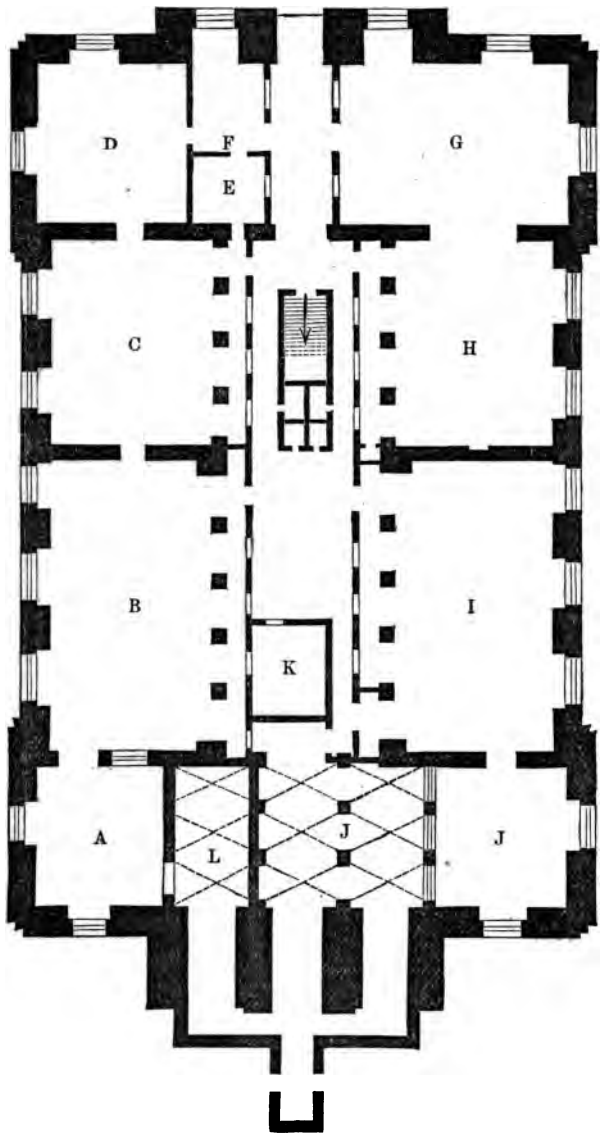
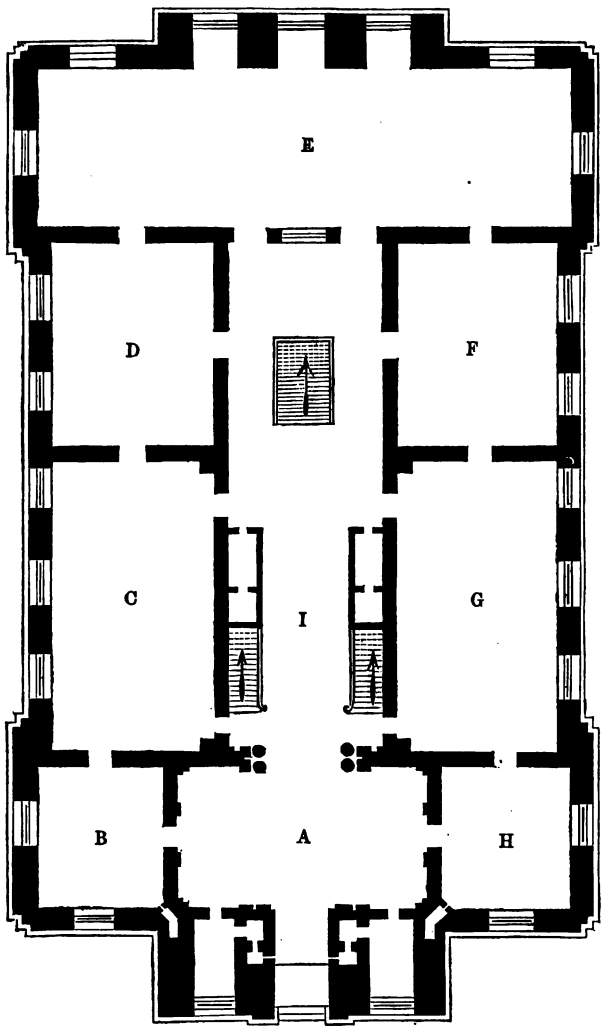
Wyman, Morrill . . Cambridge.

BASEMENT FLOOR.



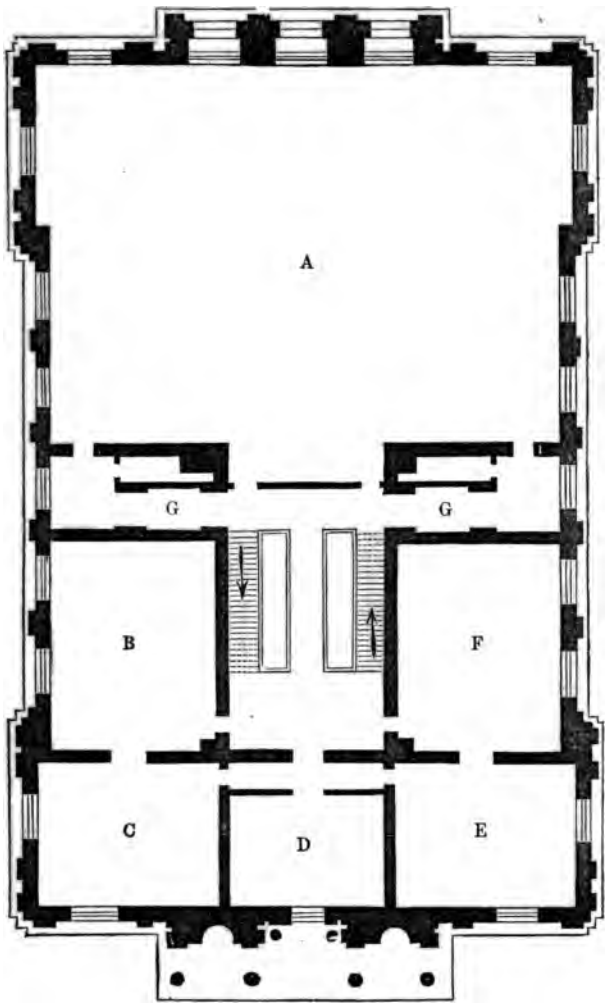
A. Professors' Chemical Laboratory, 25′ 0″ by 22′ 11″.
B. General and Qualitative Chemical Laboratory, 49′ 7″ by 34′ 0″.
C. Quantitative Chemical Laboratory, 35′ 8″ by 34′ 0″.
D. Quantitative Chemical Laboratory, 26′ 4″ by 24′ 0″.
E. Balance Room, 8′ by 13′.
F. Professor Wing's Private Laboratory, 16′ 0″ by 13′ 0″.
G. Mining Laboratory, 40′ 2″ by 27′ 10″.
H. Metallurgical Laboratory, 35′ 8″ by 34′ 0″.
I. Chemical Lecture Room, 49′ 7″ by 34′ 0″.
J. J. Mechanical Engineers' Laboratory, 25′ 0″ by 69′ 1″.
K. Daily Chemical Supply Room, 14′ 6″ by 12′ 0″.
L. Boiler Room, 15′ by 25′ 0″.

FIRST STORY FLOOR.



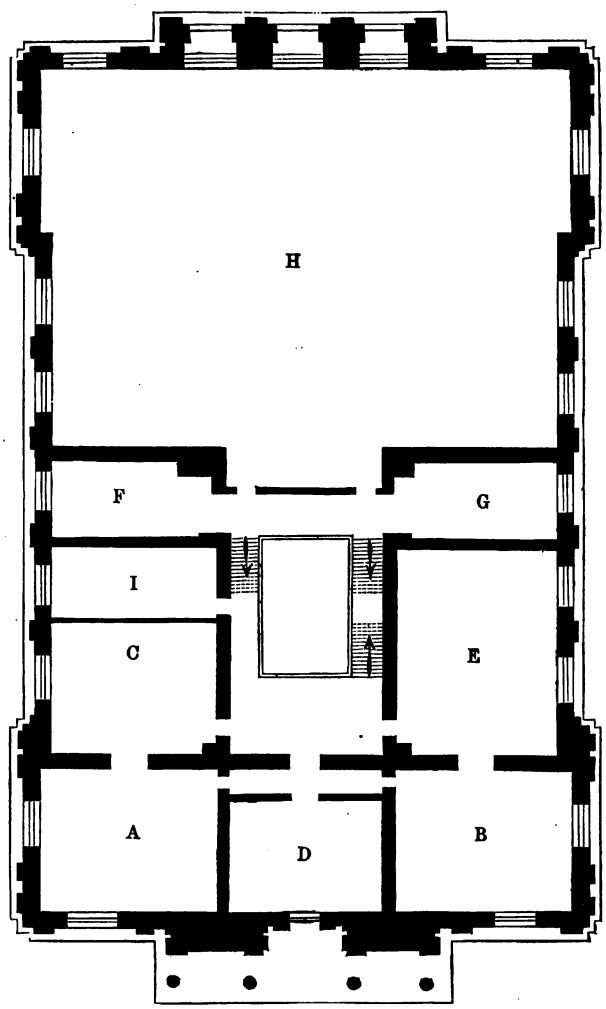
A. Entrance Hall, 42′ 2″ by 25′ 0″.
B. President's Office, 25′ 0″ by 22′ 11″.
C. Physical Lecture Room, 49′ 7″ by 28′ 3″.
D. Physical Laboratory and Apparatus Room, 35′ 8″ by 28′ 3″.
E. Physical Laboratory and Apparatus Room, 92′ 0″ by 27′ 10″.
F. Geological Lecture Room, 35′ 8″ by 28′ 3″.
G. Society of Arts Room, 49′ 7″ by 28′ 3″.
H. Secretary's Office, 25′ 0″ by 22′ 11″.
I. Stairway Hall, 87′ 3″ by 26′ 10″.

SECOND STORY FLOOR.



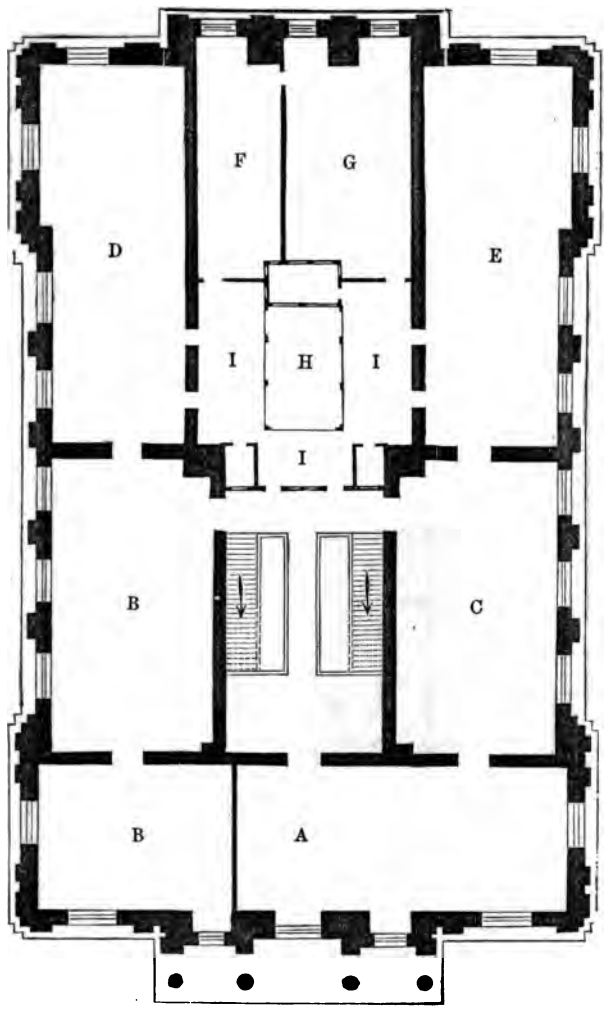
A. Huntington Hall, 92′ 0″ by 65′ 5″.
B. Mathematical Lecture Room, 34′ 9″ by 28′ 3″.
C. Civil Engineering Lecture Room, 32′ 2″ by 25′ 0″.
D. Modern Language Lecture Room, 26′ 2″ by 20′ 6″.
E. English Lecture Room, 32′ 2″ by 25′ 0″.
F. Mathematical and Astronomical Lecture Room, 34′ 9″ by 28′ 3″.
G. G. Passageways to Huntington Hall.

HALF STORY FLOOR.



A. Architectural Museum, 32′ 2″ by 25′ 0″.
B. Architectural Library and Study Room, 32′ 2″ by 25′ 0″.
C. Architectural Museum, 28′ 3″ by 20′ 9″.
D. Natural History Lecture Room, 26′ 2″ by 20′ 6″.
E. Prof. Richards' Lecture Room, 34′ 9″ by 28′ 3″.
F. Prof. Atkinson's Study, 28′ 3″ by 14′ 2″.
G. Prof. Hunt's Study, 28′ 3″ by 14′ 2″.
H. Huntington Hall.
I. Prof. Howison's Study, 28′ 3″ by 14′.

THIRD STORY FLOOR.



A. Reading and Study Room, 62′ 0″ by 25′ 0″.
B. B. Civil Engineers' Drawing Rooms, 49′ 7″ by 28′ 3″.
C. First Year's Drawing Room, 49′ 7″ by 28′ 3″.
D. Mechanical Engineers' Drawing Room, 65′ 5″ by 26′ 0″.
E. First Year's Drawing Room, 65′ 5″ by 26′ 0″.
F. Mechanical Engineering Lecture Room, 37′ 0″ by 17′ 0″.
G. Mathematical and Descriptive Geometry Lecture Room, 37′ 0″ by 28′ 0″.
H. Model Room, 21′ 0″ by 13′ 0″.
I. I. I. Passageways.

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

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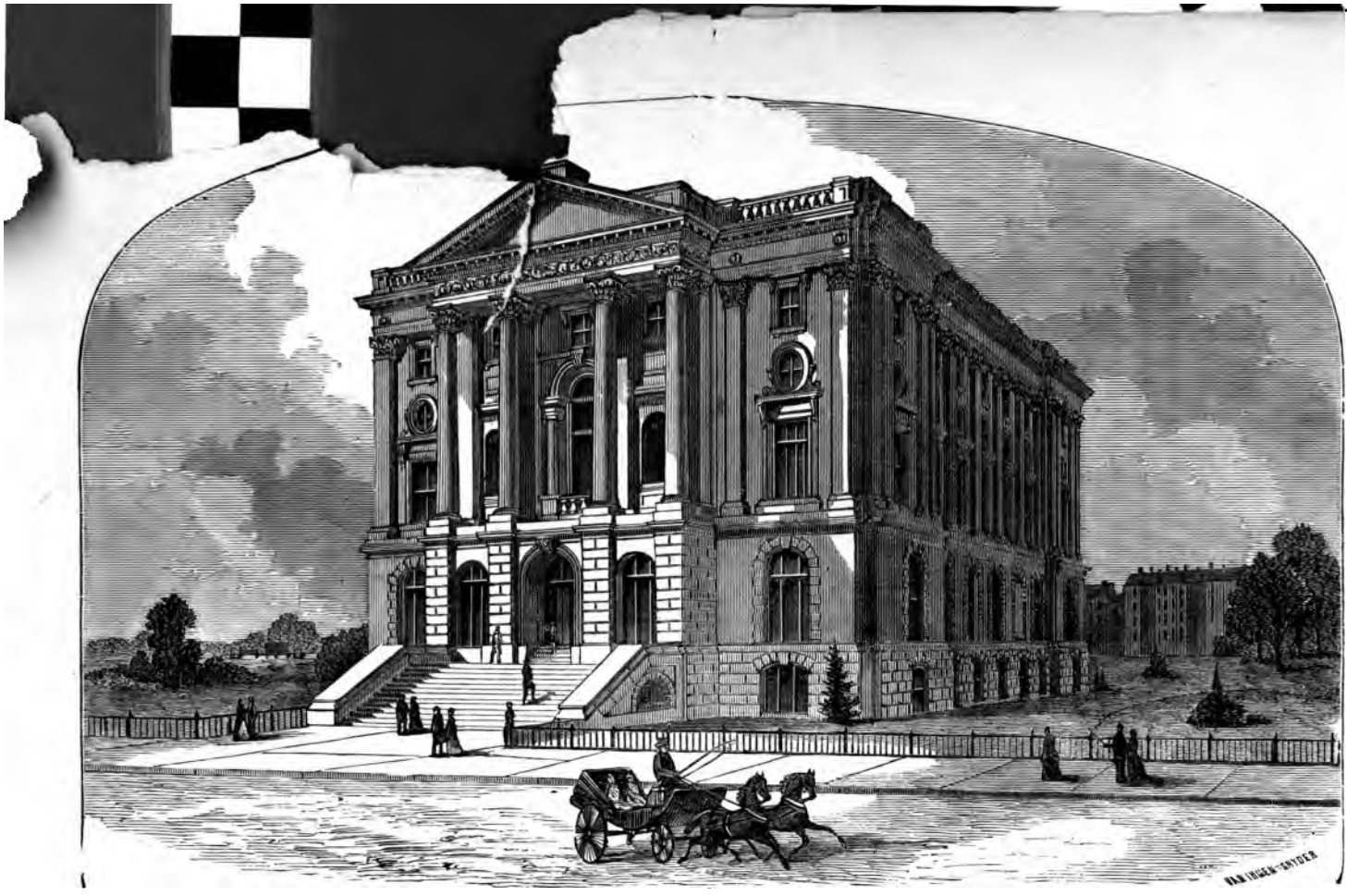
PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1877.

BOSTON:
PRESS OF A. A. KINGMAN.
1878.



INSTITUTE BUILDING.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1877.

BOSTON:
PRESS OF A. A. KINGMAN.
1878.

Extracts from Acts of the General Court of Massachusetts, in relation to the Massachusetts Institute of Technology.

Act of Incorporation. "William B. Rogers [and others named], their associates and successors, are hereby made a body corporate, by the name of the MASSACHUSETTS INSTITUTE OF TECHNOLOGY, for the purpose of instituting and maintaining a Society of Arts, a Museum of Arts, and a School of Industrial Science, and aiding generally, by suitable means, the advancement, development, and practical application of sciences in connection with arts, agriculture, manufactures, and commerce."

Chapter 183, *Acts and Resolves of* 1861.

Grant of Public Lands. "When the Massachusetts Institute of Technology shall have been duly organized, located, and established, ... there shall be appropriated and paid to its treasurer, each year, on the warrant of the Governor, for its endowment, support, and maintenance, one third part of the annual interest or income which may be received from the fund created under and by virtue of the 130th chapter of the Acts of the 37th Congress, at the second session thereof, approved July 2, 1862 [giving Public Lands to the States in aid of instruction in Agriculture, the Mechanic Arts, and Military Science and Tactics]. . . . . Said Institute of Technology, in addition to the objects set forth in its Act of Incorporation [as above quoted], shall provide for instruction in military tactics."

Chapter 186, *Acts and Resolves of* 1863.

Power to confer Degrees. "The Massachusetts Institute of Technology is hereby authorized and empowered to award and confer degrees appropriate to the several courses of study pursued in said Institution, on such conditions as are usually prescribed in universities and colleges in the United States, and according to such tests of proficiency as shall best promote the interests of sound education in this Commonwealth."

Chapter 247, *Acts and Resolves of* 1868.

CONTENTS.

	Page.
President's Report	vii–xvi
Secretary's Report of Society of Arts	1–29
New By-Laws	1
Uses of Corundum	3
Agriculture in Massachusetts	4
Industrial Education	6
The Russian System	6
Trade Schools	8
Combustion	8
Fuels	9
Natural and Artificial Draughts	9
Covering of Pipes and Boilers	10
Bridge Walls	10
Dignity and Necessity of Labor	10
Automatic Register	11
Combustion	11
Self-Testing Gauge	13
Steam Regulating Valve	13
Household Sanitary Science	14
Proper Moisture in the Air	14
Co-ordinate Surveying	15
Chase Governor	16
Hydraulic Elevator	17
Improved Orrery	17
Merrimac Lead Mine	17
Magnetic Motor	18
Electric Clock	18
Copying Designs	19
Improvements in Telephony	20
Membership of Society of Arts	21
School of Industrial Science	21
Lowell Free Courses	23
Meetings of the Corporation	23
Report on School of Mechanic Arts	24
List of Graduates in 1876–77	28
Department of Philosophy	30
Department of Military Science and Tactics	31
Department of English and History	33
Department of Modern Languages	41

	Page.
Lowell Free Courses for 1876–77	48–52
General and Qualitative Chemistry. Prof. Nichols's Report	48
Elementary Geology. Prof. Hunt's Report	49
The Philosophy of Government. Prof. Howison's Report	49
Practical Mechanics. Prof. Lanza's Report	51
Abstracts of Theses by Graduates of 1876–77	53
The Central Avenue Bridge, Dorchester, Mass., by H. H. Carter	53
Sea Walls of South Boston Flats, by Martin Gay	54
The Lowell Water Works, by Joseph P. Gray	55
The Charles River Bridge at Newton Upper Falls, by Edward Grover	55
The Double Lattice Parker Iron Bridge across the Merrimack River at Lowell, by Richard A. Hale	60
Highway Bridge across the Merrimack River, between Groveland and Haverhill, by George W. Kittredge	61
The New Bedford Water Works, by C. F. Lawton	61
The Lawrence Water Works, by B. C. Mudge	62
The Newton Water Works, by A. L. Plimpton	64
Design for an Iron Railway Bridge, with a consideration of the Principles determining the Design, by George F. Swain	66
The Ashtabula Bridge, by Frank E. Wiggin	67
A Review of a Continuons Brake Trial, by William H. Beeching	67
The Westinghouse Air Brake, by George W. Chapman	68
Double Valves as applied to the Rider Engine, by Linus Faunce	69
The Construction and Use of a Mercury Column, by Chas. H. Fisher	69
Boiler Incrustation, by Joseph Kirk	70
On Link Motion, by Cecil H. Peabody	72
The Vershire Copper Ore and its Metallurgical Treatment, by George Bartol	73
Investigation of the Institute Ore-Washers, by W. C. Flint	74
On some methods for the Extraction of Nickel and Cobalt from their Ores, by John E. Hardman	76
On the Smelting of a Silver-lead Ore from the Merrimac Mine, by Henry D. Hibbard	76
Report on the Working, for Silver and Gold, of a Middle Grade Product from Ore of the Merrimac Mine, by Walter Jenny	79
Treatment of Vershire, Vt., Copper Ore, by H. C. Southworth	81
Investigation into the Working of the Institute Ore-Concentrating Machines, by Thomas F. Stimpson	82
Experimental Working, by Wet and Dry Methods, of a Low Grade Silver and Gold Ore, from Newbury, Mass., by F. W. Wood	85
Design for a Steam Fire Engine House, by J. Williams Beal	87
A Town Hall, by Geo. W. Capen	87
A Design for a Steam Fire Engine House, by W. E. Chamberlin	88
Design for a Railroad Station, by Pierce P. Furber	89
On an Impurity found in Commercial Acetone, by John Alden	90
The Relations of Carbon to Iron, and its Determination by the Chlorine process, by Charles S. Bachelder	91
Lowell Department of Industrial Design for 1876–77	92
Members of the Society of Arts	95

THE PRESIDENT'S REPORT.

To the Corporation of the Institute: —

I have the honor to submit my report for the year ending September 30, 1877.

The following resignations have taken place during the year:

Edward C. Pickering, S. B., Thayer Professor of Physics, and Director of the Rogers Laboratory.

William E. Hoyt, S. B., Instructor in Civil Engineering and Stereotomy.

William Foster, Assistant in the Mining and Metallurgical Laboratories.

Lewis M. Norton, Assistant in Quantitative Analysis.

Charles C. R. Fish, Assistant in General Chemistry and Qualitative Analysis.

James B. Stanwood, S. B., Assistant in Mechanical Engineering.

Clarence L. Dennett, S. B., Assistant in Mechanical Engineering.

Thomas W. Robinson, S. B., Assistant in Quantitative Analysis.

In the resignation of Professor Pickering the Institute has sustained an exceptional loss. His connection with the School, as Assistant and Professor, extended over a period of just ten years, an account of which will be found in his report for 1876. This historical sketch so plainly states the origin and growth of the laboratory method of teaching physics in the Institute, and is so full a summary of what the department has accomplished under Professor Pickering's direction, that I need only again ask your attention to it.

We are fortunate in having a Professor and Assistants who have been educated in the department, and are familiar with its spirit and methods, to continue the work.

I wish here to express, in behalf of the Corporation and Faculty, the indebtedness of the School to Professor Pickering, and to wish him every success in his new field of labor.

The following are the appointments for 1877–78.

Silas W. Holman, S. B., Assistant in Physics.

John B. Henck, Jr., S. B., Assistant in Physics.

Edward A. Handy, S. B., Assistant in Civil Engineering.

Henry M. Waitt, S. B., Assistant in Civil Engineering.

W. Bugbee Smith, A. B., Assistant in Mechanical Engineering.

Charles T. Main, S. B., Assistant in Mechanical Engineering.

Frederick A. Emmerton, S. B., Assistant in the Mining and Metallurgical Laboratories.

John Alden, S. B., Assistant in Quantitative Analysis.

Albert H. Low, S. B., Assistant in Quantitative Analysis.

John E. Hardman, S. B., Assistant in General Chemistry and Qualitative Analysis.

Henry K. Burrison, S. B., Assistant in Mechanical and Free Hand Drawing.

George F. Underwood, Assistant in Architecture.

Attendance and Graduation. The whole number in attendance during the year was 315, an increase of 16 over the previous year. For classification and other items, see page 21 of the Secretary's report. The following table shows the attendance of each year since the organization of the school, properly classified, together with the number of graduates for each year. The last two columns give the percentages of those classified as regulars during the first and second years who graduated. Many students enter the school and take the full course during the first year without intending to graduate, and others fail from various causes. The last column probably more nearly represents the true relation between those who have graduated, and those who entered with the intention of so doing.

Of 202, the whole number of graduates, 81 have graduated in the department of Civil Engineering, 34 in Mechanical Engineering, 41 in Mining Engineering, 7 in Building and Architecture, 21 in Chemistry, 1 in Metallurgy, 2 in Natural History, 4 in Physics, 9 in Science and Literature, and 2 in Philosophy.

Year.	Total.	Special students.	Regular students.				No. of graduates.	Percentage of 1st year.	Percentage of 2d year.
			1st year.	2d year.	3d year.	4th year.			
1864–65	27								
1865–66	72	9	32	31					
1866–67	137	27	64	24	22				
1867–68	167	43	56	37	14	17	14	.52	.52
1868–69	172	63	57	23	22	7	5	.16	.21
1869–70	206	54	68	45	24	15	10	.16	.27
1870–71	224	77	73	36	17	21	17	.30	.74
1871–72	264	84	91	38	33	17	11	.19	.24
1872–73	375	140	115	61	27	32	25	.37	.69
1873–74	310	128	68	59	34	21	18	.25	.47
1874–75	288	117	36	55	45	35	28	.31	.46
1875–76	299	117	66	30	43	43	42	.37	.71
1876–77	315	180	36	42	24	33	32	.47	.58

Abstracts of the theses by graduates of 1876–77 will be found on pp. 53–91.

There have been no radical changes during the year in any of the departments which call for an extended statement. It will be sufficient briefly to note a few points, referring to the Catalogue and past Reports for full details concerning courses of study and appliances.

In the department of Architecture there is a steady increase in the number of students who enter upon and continue the regular course to the end of the four years, and take the degree. This full course involves the theory of construction as well as of design, and it is noteworthy that in all the theses of graduates the engineering side of the problem selected for discussion is treated with care and completeness. There is a growing feeling among this class of students that any deficiencies on the

side of design can be more readily made up after graduation than on the side of construction. It is to be hoped that the time is not far distant when a large proportion of the students in this department will prefer, and be able, to take the full course.

The Steam Laboratory of the department of Mechanical Engineering has been increased by the addition of a mercury column and other appliances, and is in excellent condition. The student has now the means of practically solving all the important questions upon the nature and use of steam which arise in his course of study, or practice.

The Mining and Metallurgical Laboratories have been gradually increased in capacity and efficiency. Iron ores have at last been included in the course of practical metallurgy. The processes in ore-dressing have been made almost wholly automatic, and these laboratories are now able to handle ores in large quantities.

Besides the education of our own students, they are beginning to be used by the public for the solution of problems in which New England, through the discovery of new mining localities, has a rapidly growing interest. It is but simple justice to refer to the untiring zeal, energy and skill with which Professor Richards has developed this element of his professional work, without in the least sacrificing or lowering the scientific side of the course. He has the satisfaction of knowing that no other mining school offers its students equal practical facilities.

The Chemical department, with its increased space in the new building (see cut, page 98), is in a very satisfactory condition; but the main building would be much improved if the department had one of its own, better adapted to its wants; and it is my duty to repeat that it should not be permitted to remain in the present building any longer than can be avoided.

The Women's Laboratory has been in all respects a gratifying success, due to the high attainments of its students, and to the time and attention which Professor Ordway has devoted to it,

assisted by the zeal and able co-operation of Mrs. Professor Richards.

The Department of Military Science and Tactics, in the charge of Lieut. Hubbell, continues to be entirely satisfactory to both Faculty and students. So far as we can learn, it is only in those colleges where this instruction has been made compulsory and efficient, that it has not been a source of annoyance and demoralization.

It will be seen from Mr. Kastner's report that the students in the Lowell School of Design, through the kind aid of several loom manufacturers, have now the opportunity to learn how to weave their own designs. This will improve the chances of those who succeed, to secure desirable situations.

The new School of Mechanic Arts. It was at first supposed that the general aims of this school could be fully accomplished, and that at the same time the course of studies would be a proper preparation for those wishing to enter the higher departments of the Institute. A brief experience, however, and further consideration, soon showed that the two aims were incompatible. A large proportion of the pupils, who enter this school, have no intention of pursuing an extended course of engineering studies, but desire in the shortest time to prepare for entering upon some industrial pursuit. It has been found best to keep the wants of such students solely in view, and not attempt to provide for the few who may wish to continue their studies. Its exact relation to the advanced work of the Institute may be learned from the report of the Faculty, to be found on page 24. The only aid which this school can render to those wishing to enter the regular courses of the Institute, will be the opportunity to make up special deficiencies in studies embraced in its course of instruction.

The Mechanic Art Shops. The plan announced in my last report, of building up a series of shops in which to teach the

students in the department of Mechanical Engineering and others the use of tools, and the fundamental steps in the art of construction, in accordance with the Russian system, as exhibited at Philadelphia in 1876, has been carried steadily forward; and I have now the pleasure of announcing its near completion. The proposed shops are: —

In wood, I, Carpentry and Joinery; II, Wood Turning; III, Pattern Making: in iron, I, Vise Work; II, Forging; III, Foundery Work (moulding and casting); IV, Machine Tool Work. A full report upon the course of instruction in each of these shops will be given hereafter.

In my last report I had the pleasure of informing you that the Director of the Imperial Technical School of Moscow had been instructed by his Government to duplicate the exhibit of that school at Philadelphia, for the Institute of Technology. This very valuable gift has arrived in excellent order, of which the following is a summary. The catalogue which accompanies the collection will be printed in detail in connection with my report upon this system of instruction as carried out here, up to and including 1877–78.

SUMMARY OF CATALOGUE.

I. Collection of samples for the successive learning of wood turning. Part I. Exercise models of various channelings and other simple forms. (Ten samples.) Part II. Casting-mould models of machine details. (Thirty-six samples.)

II. Collection of samples for the successive learning of joinery and pattern making. (Thirty-six samples.)

III. Collection of patterns for iron castings. (Sixteen samples.)

IV. Samples for the successive learning of blacksmiths' manipulations. (Seventy-seven samples.)

V. Collection of samples for learning metal-turning. (Fifty-three samples.)

VI. Models of drills and countersinks to six times the ordinary size. (Fourteen samples.)

VII. Cutting parts of files increased to twenty-four times the ordinary size. (Eight samples.)

VIII. Collection of samples for the successive learning o vise work. (Forty samples.)

IX. Collection of samples of riveted joints. (Eighteen samples.)

X. Collection of samples in iron welding. (Twenty-four samples.) Each sample consists of two parts; the first represents the details of the piece prepared for welding, and the second is the welded piece.

The whole collection contains 320 pieces of exquisite workmanship, the educational value of which can hardly be overestimated.

Legation of the United States,
St. Petersburg, June 11, 1877.

Prof. J. D. RUNKLE,
Technological Institute, Boston.

SIR: — Referring to your letter of October 16th, I now have the honor to enclose you a translation of a letter received from the IV Section of His Majesty's Chancellery, which explains itself.

I have made, in behalf of your Institute, a proper acknowledgment of the kindness both of Prince Pierre d'Oldenbourg and of His Majesty the Emperor.

I am, Sir, your obedient servant,
HOFFMAN ATKINSON,
Chargé d'affaires.

St. Petersburg, 24 *May (*5 *June)* 1877.
IV Section of the Chancellery of His Majesty the Emperor.

Prince Pierre d'Oldenbourg has the honor to inform Mr. Boker, Envoy Extraordinary and Minister Plenipotentiary of the United States, that the wishes of the Technological Institute of Boston, to introduce the system of instruction in Practical Mechanics adopted by the Technical School of Moscow, was placed before the Emperor.

It has pleased His Imperial Majesty to order to be made a collection of different models at the Technical School of Moscow, and to make a present of them to the Technological Institute of Boston.

Profiting by this opportunity to tender his respects to Mr. Boker, Prince Pierre d'Oldenbourg believes that he should add, that the Honorary Curator directing the Technological School of Moscow has been informed of this supreme order to take the necessary measures for its execution.

Legation of the United States.
St. Petersburg, October 29, 1877.

JOHN D. RUNKLE, Esq.,
President Mass. Institute of Technology.

DEAR SIR: — Yesterday I received from the Moscow School of Technology eight cases of models intended for the Institute over which you preside. These cases I have shipped to you by the Wilson Line, Messrs. Sanderson & Co., agents, directly to Boston. I congratulate you on the fact that they reached me before the closing of the navigation, so that you will receive your models shortly after the arrival of this letter. . . . . .

I am, Sir, your obedient servant,
GEORGE H. BOKER.

The following, properly engrossed, has been transmitted to the Legation of the United States at St. Petersburg: —

To His Imperial Highness,
Prince PIERRE D'OLDENBOURG,
St. Petersburg, Russia.

At a meeting of the Corporation of the Massachusetts Institute of Technology, held November 20, 1877, a communication from his Excellency, Hon. George H. Boker, American Minister at St. Petersburg, was read, announcing the gift to this Institute of eight cases of models, illustrating the system of Mechanic Art education, as devised and so successfully applied at the Imperial Technical School of Moscow. The undersigned have been charged with the agreeable duty of transmitting to His Imperial Highness the following resolutions: —

Resolved, That the Corporation of the Massachusetts Institute of Technology takes this opportunity to cordially congratulate His Imperial Highness, Prince Pierre d'Oldenbourg, that, at the Imperial Technical School of Moscow, education in the Mechanic Arts has been for the first time based upon philosophical and purely educational grounds, fully justifying for it the title of the "Russian system."

Resolved, That this Corporation hereby tenders its grateful thanks to His Imperial Highness for his most valuable gift, with the assurance that these models will be of the greatest aid in promoting Mechanic Art education not only in the School of this Institute, but in all similar schools throughout the United States.

We have the honor to be
His Imperial Highness'
Obedient servants,
WILLIAM B. ROGERS,
JOHN D. RUNKLE,
SAMUEL K. LOTHROP.

The Restaurant. In the year 1874–75 the experiment of fitting up a lunch room in the gymnasium was tried, which was so successful that better accommodations were provided early in the following year.

It has been continued, and is now in a satisfactory condition. Besides our own students, and others connected with the Institute, it is patronized by students of the school connected with the Museum of Fine Arts, and some others, and this patronage aids in its support without incommoding those for whom it was especially established.

It has largely diminished the practice on the part of our students of bringing a lunch from home, and has in proportion promoted their health. It is almost impossible for a student, who lives far from Boston, and must reach the Institute by nine o'clock and remain all day, to depend upon a cold lunch, almost always taken at irregular times, to preserve his health in its full vigor. I am satisfied that this restaurant has been an important means in improving the health of many of our students; and for this reason, if no other, it should secure the interest and support of the Corporation, so far as necessary to its continued success.

In conclusion, I will say that as a whole the school has never been in a state of higher efficiency than at the present time. Our great and pressing need is additional funds; and without

immediate relief, we must either discontinue some of the departments, or cut down the salaries already too small, or more probably both. The fee for those taking the full course is $200 per annum, and it is clearly out of the question to think of increasing the income by raising the tuition. It is even now far beyond the means of many deserving students.

The value of the Institute as an agency in developing and diversifying the industries of the State can only be maintained by increasing its funds. I can not think that the large sums which have already been contributed towards the establishment of our school, and particularly the large educational facilities and experience gathered together, shall be allowed to fail of the highest results for the want of additional means.

JOHN D. RUNKLE, *President.*

SECRETARY'S REPORT FOR 1876–77.

There have been held during the year thirteen meetings of the Society of Arts.

NEW BY-LAWS.

Nov. 23, 1876. This meeting was taken up by a discussion of the best way to correct certain informalities in the preparation of new By-Laws for the Society, arising from the complicated relations existing between the Corporation and the Society. The proper committee was finally chosen, which, with the committee of the Corporation, reported a new code, which was adopted by the Society March 22, 1877, and by the Corporation April 11, 1877.

The principal differences from the old code are: that the organization and administration are much simplified, and that the funds of the Society are to be held and used for its objects, under the direction of its executive committee, with the approval of the President. It is believed that, with this simpler organization and extended powers, a greater interest will be excited in the objects of the Society, and that the number of members actively engaged in mechanical pursuits will be considerably enlarged.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement and development in connection with arts, agriculture, manufactures, and commerce.

The Society invites all who have any valuable knowledge of this kind, which they are willing to contribute, to attend its meetings, and become members. Persons having valuable inventions or discoveries, which they wish to explain, will find a suitable occasion in the Society meetings, under certain regulations; and while the Society will never indorse by vote or diploma, or other official recognition, any invention, discovery, theory, or machine, it will give every facility to those who wish to discuss the principles and intentions of their own machines or inventions, and will endeavor at its meetings, or through properly constituted committees, to show how far any communications made to it are likely to prove of real service to the community.

The Members may be enrolled in divisions, under the following heads, according to the taste or preference of the individual; each division to constitute a committee upon the subjects to which it appertains: —

(1.) On Mineral Materials, Mining, and the Manufacture of Iron, Copper, and other Metals.

(2.) On Organic Materials, — their Culture and Preparation.

(3.) On Tools and Implements.

(4.) On Machinery and Motive Powers.

(5.) On Textile Manufactures.

(6.) On Manufactures of Wood, Leather, Paper, India-Rubber, and Gutta-Percha.

(7.) On Pottery, Glass, Jewelry, and works in the Precious Metals.

(8.) On Chemical Products and Processes.

(9.) On Household Economy; including Warming, Illumination, Water-supply, Drainage, Ventilation, and the Preparation and Preservation of Food.

(10.) On Engineering, Architecture, and Ship-building.

(11.) On Commerce, Marine Navigation, and Inland Transportation.

(12.) On Agriculture and Rural Affairs.

(13.) On the Graphic and Fine Arts.

(14.) On Ordnance, Fire-arms, and Military Equipments.

(15.) On Physical Apparatus.

Any member may belong to more than one of the above-named Committees of Arts.

USES OF CORUNDUM.

Dec. 14. Mr. C. W. Jenks read a paper, illustrated by charts and specimens, on the uses of the mineral corundum in the arts.

Corundum, in its granular and gem forms, has been long known, having been used as an abrasive second in cutting qualities only to the diamond; and in gems, as sapphire, ruby, emerald, etc., of more value even than the diamond. The corundum emerald is specially rare and valuable, being pure alumina, much harder than the silicious emeralds. It was well known to the ancient Hebrews, Persians, and Hindoos.

Extensively used as an abrasive, and widely spread over the earth, it has not been legitimately mined until within the last five years; it has been chiefly found on the surface after rains. Every one of its varieties is extensively mined in the islands of the Ægean sea, in Asia Minor, and in an impure form in this country.

He suggested that the hieroglyphics worked upon the Egyptian monuments, of a stone so hard as to speedily blunt the hardest steel, were made by tools of corundum; at any rate, this mineral will cut the Egyptian granite and the hardest diamond. If it be true that one mine of emery is worth more to a manufacturing people than many mines of gold, this substance owing its value as an abrasive to its forty or fifty per cent. of corundum (which has a hardness of 7, the diamond being 10), what must be the value of pure corundum, which stands at 9? In the rapidly-increasing field of labor for which emery is used, the diamond is too expensive for extensive use; and this the corundum, by its pure quality and better mode of application, will accomplish cheaply and well in the case of granite, steel, the harder alloys for gun-metal, rolls for paper-making machinery, and finishing steel surfaces.

He exhibited a new sapphire wheel of nearly pure corundum. This works wet or dry, heat and acids having no effect upon it; it brings a steel tool rapidly to a cutting edge without heat or

loss of temper, as it cuts so rapidly that the slight friction has no time to develop heat. In this way it does 30 per cent. more work than the best emery, much work that emery can not do at all, and much now done by the diamond.

The corundum gems, all with the prefix of "oriental," are the sapphire, ruby, asteria, emerald, topaz, amethyst, girasol, chatoyant, and white sapphire (the last often used for the diamond). All of these have been found, of more or less purity, among the Blue Ridge mountains of western North Carolina. Both forms, the massive and the gems, are found there in the same mountain, showing that the mineralogical and geological conditions of the two are not unlike, as was supposed from their occurrence in different localities in the old world. There corundum is found in the beds of streams, or in or near their banks, as water-worn pebbles, in a secondary formation of a clayey conglomerate. It is found here also in a native matrix of ripidolite, between hanging and foot walls of serpentine, apparently undisturbed, and yet with all the appearance of water action. He had never seen any specimen in this country or in Europe which he could not duplicate from the North Carolina mine. The discovery of corundum in place is a matter of great scientific interest.

The material is stamped in the usual manner, and afterward roughly or finely ground, according to the use to be made of it. It is only about 15 per cent. more expensive than emery, and apparently does a better and more extended work.

AGRICULTURE IN MASSACHUSETTS.

Dec. 28. Mr. Albert L. Murdock, of Boston, made a communication on the "Decline and Redemption of Agriculture in Massachusetts and the United States," illustrated by maps and charts, and an extensive series of grains, especially wheats, from all parts of the world.

It is a general belief and statement that the agricultural lands of Massachusetts are exhausted; this he thought was not founded on fact. It is true that 148 towns have lost, during the last

twenty years, from 2 to 61 per cent. of their population, and from 8 to 60 per cent. of their products; the people have gone to the manufacturing centres, and our manufactures have increased at the expense of our agriculture, with a consequent large decrease in the value of farms. And yet, with all this decline, there is a production, per acre cultivated, of 35 per cent. more than twenty years ago, and 20 per cent. more in money per bushel or ton is obtained from the products of the farm.

Could three-tenths, even, of these abandoned lands be cultivated, the importation of grain from other States would be stopped. When it is remembered that a million dollars is sent out of the State every week for food that we might easily produce ourselves, and that every sixth man is out of employment, the importance of the question is evident.

The redemption of our agriculture may be brought about in various ways: — by the redemption of our salt marshes by dyking; he instanced a remarkable case in this connection at Marshfield. We do not realize this decline, being deceived by the greater yield from a few acres from superior methods of cultivation; we want more acres under cultivation, and then the modern superior methods would produce all we require. He advocated the establishment by each town of a scholarship in the Agricultural College at Amherst, with the understanding that the incumbent after graduation should reside in the town, and give one afternoon each week for the information of his townspeople, for three years, or else pay back to the town half the cost of his tuition.

He also advocated the establishment of experimental stations by the State, to be cultivated in the best and most economical manner, paying special attention to the relations of the chemical constitution of grains, etc., to the characters of soils, developing thus the best methods of cultivation and the value of fertilizers. Increased production and the employment of idle hands would then be united for the material advantage of the State.

Mr. C. L. Flint, while admitting the general accuracy and importance of Mr. Murdock's remarks, stated that farming was still profitable in the State, not in the production of the cereal grains, but in raising the vegetables and small fruits which find a ready and remunerative sale in the numerous manufacturing centres which have sprung up all over the State, crowding out the old farm agriculture. It is only labor diverted into other and perhaps more profitable channels.

INDUSTRIAL EDUCATION.

Jan. 11, 1877. A paper by Rev. Dr. Bartol was read on the "Social and Political Economy of Universal Industrial Education." Industrial education is economy of health; exercise, motion of body and soul together, is a law which is punished by debility and disease, when broken. Industrial education would make the whole people honest, open generous livelihood to all, turn the State into a bee-hive of industry, relieve the charitable societies, depopulate the prisons, abolish poverty and the alcoholic desire, and substitute the enjoyment of music and the fine art gallery for the haunts of vice. It would detect and render available the mechanical and artistic genius, which is now often lost to the world, or accidentally discovered. Labor has been considered an equivalent of drudgery and degradation too long; industrial education would convert it into interest, dignity, honor.

THE RUSSIAN SYSTEM.

President Runkle then explained the Russian system of Shop-work education, as far as it had been adopted by the Institute. The object is to educate the *hand* as well as the *mind*, without which no system of technical education is complete. The difference between *in*-struction shops and *con*-struction shops must be borne in mind, as most of the adverse criticisms of the system have arisen from ignorance or misapprehension of this vital point. The hand is instructed by the use of tools just as the mind is disciplined by mathematics, chemistry, etc., for develop-

ment, for *education*, without reference to the money value of the immediate products. The purpose here is to instruct as an *art*, and not to establish *manufacturing* shops and teach *trades*. The skillful hand can afterward readily adapt itself to any manufacture.

The *con*-struction part of the great Russian schools is not to be introduced here, and the *in*-struction shops are modified to suit American needs. Though the work done be more quickly and cheaply and better done by machinery, and even though Russian shops are fitted with American-made tools, the system may properly be called Russian, as it embraces the central idea of *class* instruction of the *hand*. It makes no difference whether the forms selected can be made by machinery or not, or whether they are of any money value; the question is, whether the making of these forms is well calculated to give the pupil the skill in the use of his hands which will be a great advantage to him whether he is to make use of it in after life as a mechanic, or whether he never touches a tool again. The time spent in this teaching is so small compared to that devoted to other studies, that the pupil has all the advantages of the regular school courses, plus the manual skill which he can use, or not, as circumstances require.

Prof. Whitaker stated that the instruction in the use of the file — an instrument acknowledged by experts as one of the most difficult to use as well as one of the most important of tools — even on useless forms, would give a manual skill to these lads which was of marketable value. He exhibited specimens of work made at the Rotterdam school, showing that as an educational system this and other *con*-struction shops were of no value, and never could be; these specimens, exhibited at Philadelphia, showed a deficiency in design and detail, of money value perhaps, but useless to make a skillful workman. In his judgment, from experience in the workshops, the two years' course at the Institute, of which the filing occupied a very small portion, would save five years of apprenticeship, and make a better workman.

Mr. H. P. Langley, a mechanic of thirty-five years' experience, expressed his surprise at the excellence of the work done in so short a time, and said that he believed it would be hard to find a mechanic who, after two years' work in the machine shops, could make such accurate fitting with the file as these lads have made after a week's instruction.

Prof. Whitaker explained that the skill so rapidly acquired was due to *class* instruction by a skillful mechanic, who taught how to do the work and how not to do it; they are not left to blunder into the right way, or to pick up the necessary knowledge accidentally, or by observation of their fellow workmen; no time is lost in making mistakes, and the pupils *start* from the standpoint of an expert's knowledge and skill.

TRADE SCHOOLS.

Mr. Newell read portions of the report on Mr. S. P. Ruggles's plan, as presented to the Social Science Association. This plan proposes to take boys at the proper age, as after passing through the grammar schools, introduce them into a developing school, and then teach such of them as show an aptitude therefor the various trades. This plan, however excellent it may be, has nothing antagonistic to the Institute system, and does not pretend to effect the same educational purpose.

COMBUSTION.

Jan. 25. Mr. H. P. Langley read a paper, illustrated by diagrams, on "Combustion and the Economical Production of Steam, with results of experiments on natural and artificial draughts, and methods of preventing smoke."

The necessity for the introduction of a considerable amount of air through the grate bars, and also into the combustion chamber of a furnace, for the complete utilization of the coal gases, seems to have received too little attention in the ordinary setting of boilers. He exhibited drawings, from the work of C. Wye Williams, of various devices for the introduction of air, mostly through perforations in the bridge walls, preventing

smoke, increasing the energy of combustion, and economizing fuel. According to this author, it makes no difference in what part of the furnace or flues this air is introduced, provided that the mixture of air and gases be continuously effected, before the temperature is reduced below that of ignition, not less than 800° Fahr.

He believed that the use of *heated* air was a fallacy, unsupported either by theory or practice; by heating the air we increase its volume, but diminish the weight of oxygen in each cubic foot, and so lessen its efficacy. The use of hot air in the blast iron furnace involves quite different principles. On the contrary, combustion may be increased by condensing the air supplied to a furnace. Of course, judgment must be used to avoid the indiscriminate supply of cold air at every stage of combustion; to secure uniformity in this respect, a mechanical is better than an artificial draught.

FUELS.

The following general rules he considers as established in regard to fuels: 1. Where a strong fire is necessary, with a large and regular supply of steam for heavy work, anthracite is without doubt the best; when boilers are large and firemen numerous, this may be changed for hard coal dust mixed with soft coal, with the use of a blower; — 2. Where the amount of steam required varies much, with corresponding heavy and light fires, Cumberland, or some soft coal would be better, with a sufficient supply of air; — 3. Dust coal has the advantage of lower price, but ten per cent. more is required to do a given amount of work, more labor is necessary to feed the fires, and generally a fan or blower must be used to get the due proportion of air; when used, the fire should be very thin, three or four inches deep, the supply being put on often and in small quantities.

NATURAL AND ARTIFICIAL DRAUGHTS.

According to Peclet, one fourth of the combustible used is expended in producing the natural draught; if this heat can be

used for making steam, and a mechanical draught will cost less, the latter is to be preferred. According to Prideaux, one pound of coal expended through mechanical agency, is capable of producing a stronger current of air than five hundred pounds expended in heating a column of air to act by a chimney thirty-five feet high; on this principle, the expense of tall chimneys may be dispensed with, and complete and smokeless combustion effected in a very simple manner.

COVERING OF PIPES AND BOILER.

At a foundry in South Boston a trial for twelve weeks was made with Pictou coal, with boiler and pipes uncovered, and covered with felt; the result was 6010 pounds of coal in favor of the felt covering. He described the "Hinkley" boiler, in which the fire is entirely surrounded by water, so that no heat can escape by radiation; in a trial of nine days with hard coal, with steam at 60 lbs., 13.94 lbs. of water were evaporated per pound of coal; with Cumberland coal, in five days, with same pressure, 13.76 lbs. of water were evaporated per pound of coal. He also explained figures of the Bonta furnace, and the Jarvis, Smith, and Walker settings.

BRIDGE WALLS.

Prof. Whitaker mentioned that an engineer of this city, having used for six months a bridge wall under his boilers, beginning at nine inches distance and going up to six, at great cost of coal, had been able to make a daily saving of two hundred and fifty pounds of the hardest Lehigh coal, by raising the bridge wall up to within five inches of the boiler, or four inches with the coating of ashes on it. He believed that the bridge wall should be within four to six inches of the boiler, and with a similar curve.

Mr. Birch advocated the use of an automatic steam damper for regulating the supply of air, claiming to have evaporated fourteen pounds of water per pound of coal, and to have saved thirty tons of coal per month by the proper mechanical introduction of air.

This subject was continued at the meeting of March 8th — see bottom of page.

DIGNITY AND NECESSITY OF LABOR.

Feb. 8 and 22. Mr. Horace McMurtrie read a paper "Labor in its relations to the human organization," and on "its Dignity, Happiness, and Pleasures."

He showed that in the very structure of the human body we find proofs that labor is a blessing and not a curse; active exercise is necessary for the development of the muscles; children at play in this way exercise their muscles more than does the hardest working laborer, and this play is necessary and natural for the development of all young animals. The functions of digestion, circulation, and respiration, require active exercise for their perfect performance. Mental labor is also necessary for the development of the brain, but unfortunately has been separated from bodily labor, as of a higher grade; man endeavors to secure happiness without labor, upon the labor of others, and is prone to look with contempt upon the very means whereby he lives. The harmonious and vigorous action of all our organs is accompanied by pleasure, and any disturbance of this harmony by pain and disease.

AUTOMATIC REGISTER.

Mr. N. M. Lowe exhibited an automatic register for mechanical motions, invented by himself. The registering is effected by the action of two levers upon a train of wheels so weighted that an index will be moved by vibration, or by eccentric or concentric motions. As it may be sealed up in any movable piece of machinery, it can not be tampered with, and is therefore reliable.

COMBUSTION.

March 8. Mr. Charles W. Birch read a paper on combustion of coal, as effected by a boiler furnace of his invention, in which what he regards as warm air is introduced by a swinging per-

forated plate over an air chamber behind the bridge wall. He had previously tried, without success, a perforated plate hung at the back of a small door cut through the bridge wall from the ash pit to the air chamber, the door being kept open.

The perforated plate is placed at an angle of about thirty degrees, sloping toward the combustion chamber, the highest edge of the plate about four inches below the centre of the bridge wall; the plate set over a chamber fourteen inches long and as wide as the boilers (four feet), the sides of the chamber sloping toward a door, twelve inches square, opening into the ash pit. The air passes through the ash pit, being thus slightly warmed, then through the door into the conical chamber, and is further heated there; thence through the perforated plate to ignite the gases under the boilers.

The following were the savings of coal in the months of 1876 over the corresponding ones in 1875, when the boilers were set on the old plan: in July, 16,300 lbs.; in August, 13,000 lbs.; in September, 17,960 lbs.; in October, 12,100 lbs.; in November, 33,540 lbs.; in December, 43,790 lbs.; or a total saving, in the six months, of 136.690 lbs. The boilers were four feet in diameter, tubes fourteen feet long and of size of three inches, and forty-nine in each boiler; floor of combustion chamber on a level with that of the ash pit; bridge walls twenty-six inches thick, and built on a seven foot sweep; distance from top of centre of bridge wall to bottom of boiler five inches. He claims that with this setting he has been able to save ten per cent. of fuel, and to furnish steam for one-eighth more work. It can be easily put under most horizontal boilers, without disturbing the setting or the piping.

Mr. McMurtrie remarked that, in his opinion, the distance between the grate bars and the bottom of the boiler was, as a rule, too small; and that the cubical contents of the furnace ought to be considered quite as much as, if not more than height of bridge walls, introduction of air, etc. From above fourteen to forty inches, and the last the best, he thinks should be the distance from the grate bars to the bottom of the boiler.

Mr Langley said that, in his judgment, the best distance was, for bituminous coal thirty inches, for anthracite twenty-four inches, and for a moderate combustion twenty inches.

SELF-TESTING GAUGE.

Mr. B. B. Keyes explained, by the instrument and by drawings on the board, his self-testing gauge for steam and other pressures.

Since steam came into general use, an instrument for indicating its varying pressure has engaged the minds of inventors. Piston gauges were first introduced, but these soon gave place to the diaphragm in various forms; then Bourdon accidentally discovered that an oval-shaped tube, bent in the form of a curve, would, when pressure was exerted on the interior, tend to straighten; from this arose the spring gauge which bears his name, familiar to all engineers.

To obviate the defects arising from unavoidable accidents which render this gauge sometimes unreliable, Mr. Keyes has devised a simple attachment whereby any hollow spring gauge may be made self-testing; he utilizes not only the horizontal but the perpendicular motions of the springs, uniting them by proper mechanism, so that these motions are transmitted to the pointers; this permitted and required firmer or stiffer springs for measuring like quantities of steam than any before used, and by no pressure, within the amount indicated on the dial, can their elasticity be affected. This device prevents vibration of the pointer under action; and the springs, being held to their lowest points, and not extending beyond a line perpendicular to this point, allow no water to remain in them, subjecting them to the danger of freezing.

STEAM REGULATING VALVE.

March 22. Mr. Joseph E. Watts, of Lawrence, exhibited a steam-regulating valve, of his invention, which had been successfully tried in several manufacturing establishments during

the past year, and upon the steam-tables in the Chemical Laboratory of the Institute.

HOUSEHOLD SANITARY SCIENCE.

April 12. Mr. H. P. Langley read a paper on "Household Sanitary Science," dwelling particularly on the impurities of air, and the necessity for a certain amount of moisture in it. He described a simple device for ventilation by the windows, and exhibited several hygrodeiks.

PROPER MOISTURE OF THE AIR.

Mr. Chester B. Merrill then made a communication on the condition of air in rooms heated by steam, and explained his invention for regulating the moisture in the same. It is found by actual tests that the temperature in such rooms is kept much too high, ranging from 70° to 80°, and that the hygrometer shows only from twenty to thirty per cent. of moisture, while it should indicate sixty per cent. When steam was introduced for heating purposes, it was said that the air would be too damp; the reverse is the fact.

At zero a cubic foot of air will hold 1.8 grains of watery vapor, at 32° 2.35, at 50° 4.24, at 100° 19.12 grains. The heating of air does not dry it in the sense of taking moisture out of it; it only renders it capable of holding more, and it drinks up moisture from everything that it comes in contact with, whether our furniture or our bodies.

He exhibited in operation a steam air-moistener, invented by himself, by which he claims that the dryness of the air in our houses, one of the principal objections to heating by steam, is overcome — the humidity of the air being regulated in this way, and shown by the hygrometer as accurately as is the temperature by the thermometer.

From remarks made by various persons, it appeared that sixty per cent. of moisture was obtained with great difficulty, and would be accompanied in very cold weather with the double disadvantage of ice on the windows and cold surfaces,

and its subsequent melting and injury to dwellings. Fifty per cent. seems to be the best degree of saturation, and air of this moisture need not be so warm as is generally considered necessary in our hot and dry rooms; double windows, with a space between them of a foot, are necessary for this purpose in cold weather.

CO-ORDINATE SURVEYING.

April 26. Mr. Henry F. Walling read a paper, the object of which was to point out a simple method in which the high degree of precision of the "Coast Survey" work may be made available in the ordinary operations of surveyors where the Coast-Survey triangulations have been carried, and to call attention to the importance of these triangulations over the entire country.

In land conveyances permanent landmarks, position of boundary lines relative to each other, and accurate statements of dimensions are generally omitted; fences, walls, hedges, ditches, streams, shore lines, boundary stones, etc., do not remain unchanged; the compass is liable to great uncertainty from the irregular action of the magnetic force and local disturbances; the theodolite and surveyor's transit afford no greater precision in retracing obliterated boundaries unless one or more well-defined lines remain for reference; the solar compass is more accurate, but its use is limited to bright or slightly cloudy days; the direct measurement of distances by the usual rod, tape or chain, is attended with even more difficulties than the measurement of directions. In a trigonometrical survey, or the measurement of angles, on the contrary, the accuracy is such that the error is reduced to a little less than two feet in one hundred miles, which would not vitiate any measurements even in the most valuable localities.

Instead of defining the position of a point by its terrestrial latitude and longitude, he would give its "latitude and departure," or its co-ordinates, from the zero point or origin of co-ordinates for the containing areas. The advantages of this

method are, he claims: 1. The highest practicable degree of accuracy, in small or large operations; 2. Great simplicity of notation, with ease and convenience of field work and computation; 3. Facility in graphic representation; 4. Absolute certainty of locations in descriptions for conveyances, and consequent removal of a fruitful cause of litigation and dispute.

Buyers and sellers of land, lawyers and conveyancers, are familiar with the defects of the prevalent modes of surveying; scarcely one deed in a hundred contains such a description of the land as would fix its location with certainty, if its fences, walls, or other boundary lines, should be obliterated; a large part of the litigation of the country arises from the imperfect surveys, or no surveys at all, upon which such conveyances are based.

CHASE GOVERNOR.

Mr. L. E. Chase exhibited his new form of governor, prefacing his explanation by a statement of the defects of all the common forms of this instrument.

The two great enemies against which the inventor has to contend here, are friction and lost motion; since, in proportion as these are overcome, will the governor valve coincide, in time and amount, with the variations of speed in the engine. All systems of jointed arms, levers, swivels, valve stems, etc., are fatal to the required conditions, since any train of the above must engender friction and lost motion, whether the governor be centrifugal, pneumatic or hydraulic. The governer valve must be as delicate and accurate as the best spring balance, and must act with the utmost nicety through minute distances.

To remedy these difficulties, this governor is made without balls, fans, paddle wheels, jointed arms or valve stems; the valves are hung upon a spring made to revolve, and are actuated directly by the centrifugal force, without the intervention of supplementary parts; friction is thus reduced to a minimum, and lost motion is entirely avoided. He exhibited it in section and by diagrams, which would be necessary for a complete

understanding of its merits. Beside its great simplicity, the following advantages are claimed for it: no revolving balls, throwing of oil, nor gears to strip or wear out; readiness of application, as it need not be taken apart, will run in any position, or either way, and can be attached to any form of engine; perfect governing power, great uniformity of speed, and complete control over the steam pressure, whether high or low; economy, as it allows no waste of steam; durability and ease of repair.

HYDRAULIC ELEVATOR.

Mr. Joseph H. Lewis exhibited in operation a model of a new hydraulic elevator for dwellings and stores. It was noted as easy of operation, economical of water, and easily adapted for variation in load, when running up or down. It differed somewhat from those in common use.

IMPROVED ORRERY.

May 10. Mr. N. M. Lowe explained a new form of orrery, of his invention. It was very ingeniously contrived to show, in a single instrument, what otherwise has hitherto required complicated and expensive apparatus. It exhibited the orbital motions of the planets in their respective planes; the seasons, months, signs of the zodiac, solstices, and equinoxes; the inclination of the earth's axis; the motions of Jupiter; the direction of the sun's rays on the earth; the places of rising and setting, and the apparent path of the sun in the heavens at the different seasons of the year; the phenomena of the midnight sun; and many other astronomical phenomena, which it is important to exhibit in schools.

MERRIMAC LEAD MINE.

This mine was discovered in 1874, when a pit was dug, and four tons of very fine smelting lead ore were taken out; the vein was found in November 1874; the ore has hitherto been shipped to New York.

Last January a lot of the poorest ore was sent to the Institute Laboratory for the experimental work of the mining students; from their experiments the value of the lead, silver, and gold per ton was carefully estimated. This was done for the double purpose of giving the students practical experience in handling work, and of trying to find a process whereby low grade ores at Newburyport could be treated with profit.

MAGNETIC MOTOR.

Mr. W. W. Gary exhibited in operation a new magnetic motor of his invention, utilizing the power of permanent magnets. He claims to have demonstrated: 1, that the polarity of an iron bar, when magnetized by induction from permanent magnets, is changed by increasing or diminishing the distance between the iron and the magnets: 2, that, according to this law, one small cell of battery may be made to operate an engine of sufficient power for sewing machines or dental engines, by using in combination with an electro-magnet powerful permanent magnets: 3, that the power of the engine is increased by the addition of permanent magnets, without additional battery power or consumption of material.

ELECTRIC CLOCK.

Mr. Thomas Hall exhibited what its inventor, Mr. Clark, of Kentucky, calls the "Perpetual Electric Clock," from its running a year and a half or two years without changing the battery or touching the clock.

In the ordinary electric clock, the swinging of the pendulum of another clock makes and breaks the circuit which sends the hands forward. In this, the weight or mainspring of the common clock is replaced by the electro-magnets; by a simple modification the hair-spring and the magnets effect the reciprocating movement, the circuit being made and broken while the wheel is travelling in the same direction. The clock, once accurately adjusted, will go without variation for about two

years, the weakening of the spring and the deterioration of the battery being about equivalent. A battery, costing about two dollars, may be placed in a closet or in the cellar, and will suffice for a clock in every room in a house, without any attention.

COPYING DESIGNS.

May 24. Mr. Thomas Hall exhibited his apparatus for copying and enlarging designs, opaque or in colors, illustrated by the lantern; the apparatus may be placed in any room ten feet high.

He compared the old, tedious, and expensive process with his rapid, cheap, and accurate method. Now the camera is used for enlarging the design on zinc or paper for the pentagraph machines, and it has many advantages over the old methods. In the old process it was necessary to make a fine outline tracing in black, on transparent paper, of all the shapes and colors in the design; this tracing was put in a camera, and the light taken from above the tracing, casting a shadow on the paper or zinc below. It took from half an hour to a week, or more, to get one of these tracings prepared for the camera, according to the size and amount of work to be traced.

In the new process, the design itself is put in the camera, and an enlarged shadow of the design is obtained on the paper or zinc in the colors in which it is painted, thereby getting a much better shadow to trace, the colors being just as they are drawn, instead of the mere outline of the colors as in the old way. By the new process are saved all the valuable time and labor necessary to make a transparent tracing, often a very important item. He had saved on one pattern some thirty to sixty dollars, and this is a specimen of what is done every day.

The advantages claimed for the new process, then, are: First — It saves much time on every pattern, thus enabling one man to do the work of two. Second — It saves the wages paid to a sketch-maker, while making transparent tracings. Third — The work is more correct, being taken from the de-

sign. Fourth — The shadow is better and more convenient to work from, as the workman can see at once just what colors he is tracing.

IMPROVEMENTS IN TELEPHONY.

Prof. A. Graham Bell gave a brief sketch of the history of telephony, and of the various ways in which he had simplified the apparatus employed. He described the original instruments, in which a battery current was used, in one of three varieties, which he called a year ago intermittent, pulsatory, and undulatory currents, characterized respectively by the alternate presence and absence of electricity upon the circuit, sudden changes in the intensity of a continuous current, and gradual changes of intensity like those in the density of air occasioned by simple vibrations. His receiving instrument then resembled a human ear, in connection with electro magnets and coils, each terminal apparatus being different from the receiving. He had ascertained that it was simply necessary to have a permanent magnet, with a simple coil with magnetized iron core, without a battery. The larger the plate the better the sound seemed to be; he had tried every size and thickness, from that of the thumb-nail to a sheet of iron four feet square, and from the thinness of tissue paper to boiler plate a quarter of an inch thick, with nearly the same results; gold-beater's skin and similar membranes in imitation of the drum of the ear were entirely unnecessary. The vibration is certainly not that of a membrane, and may be called, for want of a better name, molecular. The essentials for the telephonic apparatus, as at present constructed, are a permanent magnet, a coil, and a plate in front so placed as to vibrate freely without touching; and all these parts he has varied in many ways as to size, shape, thinness, material, etc. He finds that the thinner the coil the better the results, and he has had the best effects from a plate of soft iron, four inches in diameter and one thirty-second of an inch thick.

He exhibited a new and portable telephone, having the magnet and coil in the handle; this was passed round among the audience, who were thus enabled to hear music and conversation in a far distant room in the building. He had made a serviceable instrument which he could carry in his vest pocket.

He spoke of the social and business uses to which the telephone might be put, and drew an amusing picture of its future applications, as a time and labor saving apparatus at a moderate cost and for domestic uses.

He concluded his experiments by passing a voice through the bodies of twenty persons, standing side by side on the platform and taking hold of each other's hands. This was overcoming an immense resistance, much greater than that offered by the Atlantic cable; suggesting that, if this resistance be the chief thing to overcome, telephony may yet be substituted for telegraphy across the oceans, as it soon will be across the continents.

The meetings of the Society were then suspended till the autumn.

Of Life Members, Mr. E. B. Bigelow resigned during the year, and Messrs. J. Wiley Edmands and James McGregor died.

Mr. John Newell was elected an Associate Member. Messrs. Isaac Ames, Charles E. Buckingham, J. J. Dixwell, William Munroe, and Edmund Quincy have died during the year; fourteen have resigned, and twelve have been dropped for non-payment of fees and removal from the State. There are now on the list 59 Life, and 154 Associate Members.

SCHOOL OF INDUSTRIAL SCIENCE.

The attendance at the School of Industrial Science for the year has been 315, as follows: Graduate students, 22: Regular students of 4th year, 33; of 3d, 24; of 2d, 42; of 1st, 36; — Students not Candidates for a Degree; 4th year, 11;

3d, 7; 2d, 25; 1st, 12; Architectural students, 21; Students in School of Mechanic Arts, 23; special students in Chemistry, mostly women, 25; students in Practical Design, 47, of whom 38 were women; deduct 13, who were counted twice: = 315. Of these about five-sixths were from Massachusetts, principally from Boston and its vicinity; — from other New England States, 18: viz.; from Maine and New Hampshire 7 each, from Rhode Island and Connecticut 2 each. From other States, there were from New York 8; Illinois, 7; Ohio and Iowa, 4 each; Missouri, Texas, and California, 2 each; Georgia, Minnesota, Wisconsin, Pennsylvania, and Kentucky, 1 each; Japan, 4; Canada, 2; New Brunswick, Cuba, and the Hawaiian Islands, 1 each.

In accordance with a vote of the Corporation, the laboratory for advanced instruction in Chemistry and allied subjects for women was opened at the commencement of the year, and more than twenty, principally teachers, availed themselves of its privileges, for various periods of time and in such departments as each one felt special need. This class was under the superintendence of Prof. Ordway. A vote of the Corporation also authorized the opening of such departments of the school, as the Committee on Instruction see fit, to advanced special students of either sex, or to special classes, where it can be done without interfering with the regular work of the school. In the Department of Philosophy, Prof. Howison had a class of seven ladies, who pursued a thorough and most satisfactory course, extending through the year.

The class in "Practical Mechanism" has also been most successful.

The class in "Practical Design" has been very large, and the character of the work, fully exhibited in Philadelphia last year, has not fallen off. Decoration of tiles and table ware, and work on a loom, have been added to the course, as will be described in the Report of the Instructor, on a subsequent page.

During the year the school has lost the services of Prof. Pickering, who resigned his position as Thayer Professor of Physics to accept the post of Superintendent of the Harvard Observatory at Cambridge. Prof. Zalinski, to whose energy and perseverance the present efficient condition of the Military Department is due, was ordered back to his regiment, the time of his detail to the Institute having expired.

Thirty-two professors and teachers have been connected with the school, who have been assisted, as is customary, by several advanced students in the laboratories and in field work. The fees from students have amounted to about $45.000.

LOWELL FREE COURSES.

The Lowell Free Courses for the year were as follows:

I. *General Chemistry.* Twenty-four laboratory exercises of two hours each, on Wednesday and Saturday afternoons at 2½ o'clock, by Professor Nichols, beginning Nov. 8.

II. *Qualitative Analysis.* Twenty-four laboratory exercises of two hours each, on Wednesday and Saturday afternoons at 2½ o'clock, by Professor Nichols, beginning Nov. 8.

III. *Geology.* Eighteen lectures on Tuesday and Friday evenings at 7½ o'clock, by Professor T. Sterry Hunt, beginning Tuesday, Nov. 7.

IV. *The Philosophy of Government.* Eighteen lectures, on Monday and Wednesday evenings at 7½ o'clock, by Professor Howison, beginning Monday, Nov. 6.

V. *Practical Mechanics.* Eighteen lectures, on Tuesday and Thursday evenings at 7½ o'clock, by Professor Lanza, beginning Tuesday, Nov. 7.

These were open to both sexes over eighteen years of age, and were, as usual, well attended.

The Corporation has held ten meetings during the year.

At the meeting of May 9, 1877, the President made a detailed statement in regard to the progress, condition, and purposes of the new School of Mechanic Arts, based upon the report of the Faculty in relation thereto.

The following is the Report of the Faculty on this subject, which had received the full consideration of the Committee on the School: —

THE Committee appointed by the Faculty to consider the condition of the newly constituted Department of Practical Mechanism beg to submit the following

REPORT.

The new Department of Practical Mechanism established last year, by vote of the Corporation, is of a different character from the other departments of this school, inasmuch as the standard of age and attainments exacted of applicants is lower, the studies pursued are of inferior grade, and the course of study is shorter, no degree, of course, being given at its conclusion. In conformity with this vote, and with certain agreements entered into with the Massachusetts Mechanics' Charitable Association, workshops have been built, in which a successful course of instruction in vise-work has been carried on. This instruction has been followed by the students in the Department of Mechanical Engineering as part of their regular school work, and by volunteers from other departments of the school; by special students from outside, among whom are some of our own graduates; and by a large class of younger students, attracted by the new opportunities, for whom special instruction of an elementary character in English, French, Drawing, and Mathematics has also been provided, forming, with the shop work, a two-years' course of study. This instruction has been given in the drawing-rooms and lecture-rooms of the Institute, by some of our own number. It has been suggested that this two-years' course may prove of service in fitting boys to pass the entrance examinations of the regular course.

Your Committee have accordingly considered this work under its relations, first, to the regular students in the Department of Mechanical Engineering; second, to special students in that department; thirdly, to those younger students for whom the two-years' course is designed; and, lastly, to boys proposing by-and-by to enter our professional courses.

I. So far as relates to regular students in the course of Mechanical Engineering, or to those in any other department who may take part in it, the shop-work presents no difficulty. It obviously stands

on the same footing as any other laboratory work. The workshops are in fact and in intention one of the laboratories of the Department of Mechanical Engineering, where manual skill is acquired at the same time that a practical acquaintance with the subject-matter of the science is attained, just as in the laboratories and drawing-rooms of other departments. They are solely for instruction, and are to have no manufacturing or mercantile character whatever.

The value of this work to these students, and the amount of time properly to be given to it, are matters which your Committee have not felt themselves called upon to consider. The decision of these points lies with the head of the department, acting, of course, as in any other laboratory work, with the advice and consent of the Faculty and of Committee on Instruction.

II. Special Students may, of course, be received into this laboratory, so far as convenience permits, just as into other laboratories or drawing-rooms; and these Special Students may, agreeably to the custom in other departments, take part in such other instruction as they are qualified to profit by, under such rules as may be established. Their case, also, presents no difficulty.

If the interest that has already been shown in this work is ultimately warranted by its success, we may expect a considerable number of young men to come to us to learn the methods here pursued, in order to become teachers in similar instruction-shops elsewhere. All such students, also, would be classed as Special Students in the Department of Mechanical Engineering.

III. It might seem at first as if the students who pursue the two-years' special course above described might also be classed as Special Students in this department, their work in the instruction-shops being the same as that of the Regular Students. They are younger and more ignorant; but it might be considered, and your Committee were at first disposed to consider, that the difference was one of degree, not of kind. In the Department of Architecture, a special two-years' course has been established for the somewhat miscellaneous body of young men who appear in the catalogue as Special Students in that department, and this seemed at first to furnish a precedent applicable to the case in hand; but the difference of the two cases is an essential one. The important question is the question of age. The students

in the special course in Practical Mechanism are boys, and it is for boys that that course is intended. They need the care and discipline that school-boys require. Experience shows already that the methods adapted to our own students do not meet their case. Their studies, outside their shop-work, should be conducted in separate rooms, under the constant supervision of special instructors and disciplinarians.

Moreover, although the shop-work is the characteristic, and, in a sense, the most important part of such a course, since it is the element that distinguishes it from ordinary schooling, it by no means occupies the chief part of these boys' time. The greater part of the day must be occupied, as with other boys of their age, with reading, writing, arithmetic, and drawing, with something of natural science, and perhaps some one of the modern languages. And these studies, if judiciously chosen, need not be any less practical in character than the exercises in the workshops. The arithmetic of mensuration, for instance, with the computations involved in the elementary phenomena of physics and mechanics, would enable the student of any of the mechanic arts to cover a great deal of ground in a way at once entirely practical and eminently scientific. This is the sort of training which, in the decay of the system of apprenticeship, the intelligent workman needs. It is a training that the High Schools and Academies cannot supply, and it is entirely different from anything needed by the students in our professional courses. What is wanted is something which shall come after the Grammar School, and shall put boys in the way to become master mechanics. They need a schooling, but one neither literary nor mercantile in character; a training which, though based upon the the applied sciences, shall be entirely practical in its methods, and it is something of this sort that the instruction in practical mechanism already organized undertakes to supply.

But it seems to us a matter of regret that this instruction should have been organized exactly in the shape that it now presents. As a department in our own school it holds, as has been intimated, an entirely anomalous position, resembling the other departments only in name, and, while its real importance is obscured, tending to disparage the professional courses by its presence among them. To have ranked these students as Special Students in Mechanical Engineering would have been, in terms, more consistent with the rest of our organization; but the consistency here again would have been only nominal. These

students are not really what we mean by Special Students; besides, it would not have been fair to throw upon that department the burden and responsibility of such a charge, especially if, as may well happen, this instruction should come to include other practical arts not specially related to the work of that department, and involving the fitting up of instruction-shops with which its own students would have nothing to do. We cannot but regret that the Corporation did not establish the new work at once on a more independent footing, giving it a position so distinct from the professional training previously undertaken that we should not appear to be changing our policy or lowering our standard, while the new work should clearly appear to be a new one. If the Corporation should, even now, see fit to revise their action, and, instead of establishing a new department in this school, create a separate school, of a subsidiary character, though under the management and direction of the same Faculty, it would seem to your Committee to be the best statement of what they have in fact already done.

If this view should commend itself to the Faculty, we would recommend that the President be requested to signify the same to the Corporation.

This would not necessarily involve any increase of the work beyond its present dimensions, while it would put it on a juster footing, and one more favorable to its natural development. But whatever extension may ultimately be in store for it, the character of the work done in the instruction-shops must, for some time to come, be fixed by the requirements of the several professional departments, as it is at present by those of the Department of Mechanical Engineering; and any other instruction-shop that may hereafter be added must be, as the filing-shop is now, primarily a professional laboratory.

What experience has been already gained would seem to show that such work, being absolutely new to all, is equally well adapted to all classes of students.

IV. As to the serviceableness of such studies to young men proposing afterwards to enter the Institute as Regular Students, we do not see that it can well be made to answer the general demand for such preparatory schooling. Such a school would differ too much from the High Schools and Academies from which our students come for us to expect from it the same class of students; and even the

High Schools and Academies hardly meet our demands. But special cases may constantly arise of students ready or nearly ready to enter our classes, to whom a year of practical instruction would be of great service; and this may prove the best practicable course for some of those who apply for admission to the Institute, but are not quite prepared to pass our entrance examinations. Besides, it does not seem to us desirable that the Institute should be understood to maintain a Preparatory Department.

WILLIAM R. WARE.
JOHN M. ORDWAY.
GEORGE H. HOWISON.

BOSTON, Feb. 21, 1877.

After considerable discussion, it was voted that this instruction be given in separate rooms — that the department be known as the "School of Mechanic Arts" — that it be not regarded as preparatory to the regular school of the Institute — and that it be under the control of the Committee on the School as are all other departments of instruction in the Institute.

DEGREES CONFERRED.

At the meeting of June 5, it was voted that the Degree of Bachelor of Science be conferred on the following students, who had fulfilled all the requirements for the Degree, and who had been recommended by the Faculty and the Committee on the School: —

Henry H. Carter . . .	Roxbury	Civil	Engineering
Martin Gay	Staten Island, N. Y.	"	"
Joseph P. Gray. . . .	Lowell	"	"
Edmund Grover . . .	E. Walpole . . .	"	"
Richard A. Hale . . .	Lawrence	"	"
Geo. W. Kittredge. . .	N. Andover . . .	"	"
Charles F. Lawton . .	New Bedford. . .	"	"
Benj. C. Mudge . . .	Lynn	"	"
Arthur L. Plimpton . .	Boston	"	"
Charles E. Stewart . .	Boston	"	"
Geo. F. Swain	San Francisco, Cal.	"	"
Frank E. Wiggin . . .	Boston	"	"

William H. Beeching . .	Boston	Mechanical Engineer'g.
Geo. H. Chapman . . .	Winchester . . .	" "
Linus Faunce	Kingston	" "
Charles H. Fisher . . .	Canton	" "
Joseph Kirk	Dorchester . . .	" "
Cecil H. Peabody . . .	Chicago, Ill. . . .	" "
George Bartol	Lancaster	Mining Engineering.
William C. Flint . . .	Salem	" "
John E. Hardman . . .	Lowell	" "
Henry D. Hibbard . . .	W. Roxbury . . .	" "
Walter Jenney	Boston	" "
Harry C. Southworth .	Stoughton	" "
Thomas F. Stimpson . .	Swampscott . . .	" "
Fred. W. Wood . . .	Lowell	" "
J. Williams Beal . . .	S. Scituate	Architecture.
George W. Capen . . .	Canton	"
Wm. E. Chamberlin . .	Cambridgeport . .	"
Pierce P. Furber . . .	Cottage Grove, Minn.	"
John Alden	Randolph	Chemistry.
Charles S. Bachelder . .	Brookline	"

The subjects of the Theses and the abstracts of the same will be found in subsequent pages.

The progress and present condition of the school in its various departments, will be stated in the reports of the President and Professors.

SAMUEL KNEELAND, *Secretary.*

Boston, Sept. 29, 1877.

DEPARTMENT OF PHILOSOPHY.

To the President: —

The programme, as now established and printed in the catalogue for the current year, has been duly carried out. The work assigned for all regulars has been accomplished by them in a satisfactory manner.

In the Department proper of philosophy, there have been no *regular* students this year; but the opening of special courses to persons of either sex, in accordance with the Government's vote of May 10, 1876, resulted in the entrance of a number of young women (seven) upon the Introductory Course in Philosophy, — that laid down for the Second-year students in the Department. Their work proved to be a signal success, and four of them will continue in the Department the coming year, to take a course upon Hume and Kant.

In June last, as the contribution of the Department to the general exhibition (then contemplated, but afterwards given up) of the Institute's School of Industrial Science, an "Account of the Department of Philosophy in the Massachusetts Institute of Technology" was printed, making a pamphlet of 72 pages. It included (I) an account of our various doings from 1872 to the date of publication, fully illustrated by specimen examination-papers, (II) the theses by the men who were graduated in 1876, and (III) the *verbatim* examination-papers produced at the last Annual by the young women mentioned above. The Government are respectfully referred to this "Account" for full details of our operations during the year just closed.

Respectfully submitted,

GEO. H. HOWISON.

DEPARTMENT OF MILITARY SCIENCE AND TACTICS.

President J. D. Runkle:—

SIR, I have the honor to submit herewith my report of the Department of Military Science and Tactics for the School year ending September 30th, 1877.

I assumed charge of the Department at the beginning of the year, and finding the status of the Military Course to have been the result of careful deliberation and experiment on the part of the Corporation, the Faculty and my predecessor Lieut. Zalinski, I instituted no changes and have none to recommend. A new element however, has been added to the School during the past year, viz.; the Department of Mechanic Arts, and I respectfully recommend that the students attending this Department be required in their first year to attend drills. I think the exercise so obtained would be of benefit to them in counteracting any injurious tendency of their confined shop work, which necessitates more or less labor while in a stooping posture.

These students, should they subsequently enter the regular first year's course, would be able to pass the required examination in tactics and so omit drill for that year, while some of them, as volunteers, would be useful as officers and non-commissioned officers. The small size of the First year class during the past year, averaging about forty for drill, made it inexpedient to form a battalion. I therefore organized the Corps as a Company, retaining, however, the offices of Adjutant and Quartermaster, the duties of which were mainly clerical. During the regular drill hours instruction was given in Infantry drill, including skirmishing, and during recreation hours, volun-

teer detachments were instructed in Artillery drill, rifle practice, and military signalling. The discipline of the Corps has been good and the officers zealous and efficient. I consider them well qualified to perform the duties of their respective grades in any volunteer organization in the country. They were as follows: —

Staff Officers ranking as First Lieutenants.

Adjutant — F. R. Loring.
Quartermaster — J. H. Tibbetts.*

Line Officers.

Captain — E. C. Miller.
First Lieutenant — W. T. Miller.
Second Lieutenants — L. R. Millen and N. B. Morton.

The Second Year Class attended lectures on Discipline, Administration, Camps, Marches, Outpost duty, Military Hygiene, and the principles of Field Fortification.

Through the liberality of a gentleman interested in Military education, I was enabled to offer a prize for the best essay on a given subject. The subject discussed was; — "In this country, with a small standing army, how best to apply the maxim, 'In time of peace, prepare for war.'" There were seven competitors, all of whom evinced thought and originality in their papers. The prize was awarded to Mr. F. B. Knapp.

I am, very respectfully, yours,

H. W. HUBBELL, Jr.
1st Lieut. 1st Arty.,
U. S. A.

* Mr. Tibbetts left the Institute after the semi-annual examination. The duties of the Q. M. Dept. were faithfully performed during the remainder of the year by Q. M. Sergt. L. P. Howe.

DEPARTMENT OF ENGLISH AND HISTORY.

President Runkle : —

SIR : — I hereby present through you to the Government of the Institute of Technology, the following account of the condition and work of the department of English and History.

The Freshman Class spend two hours per week in exercises in "Rhetoric and Composition." The first object of these lessons is an elementary one; namely, to supplement the usually great deficiencies of their school education by a review of the rudiments of the subject. To this end, that part of the manuals of Rhetoric is gone over which contains the rules for the construction of sentences, the definitions of figures, and other elementary matters, and this review is accompanied by class exercises, and the requirement of a considerable amount of written composition. This, however, is but the least part in the real work needful for the formation of a good style. That object can never be accomplished through the mere learning of rules and the correction of the crude performances of beginners; but requires, as a necessary element, much and careful reading of good writers. I therefore begin as soon as possible the much-needed labor of teaching our young men *how to read*, by the critical study of selected texts, and the practical application to them of the rules and principles laid down in the Rhetorics. The recent publication in a cheap form of various series of specimens of standard writers in

rose and poetry,[1] will hereafter enable me to read with the class a varied series of complete texts without overburdening the student with the expense of costly editions of the whole works of the different authors. It also puts within our reach for critical study, typical specimens of *modern* writers.

This series of exercises seems to me to be exactly in place in the first year, and experience has proved their necessity to the great majority of the students who attend our school. In proportion to its importance, the time allowed it on our schedule is necessarily short, and it is greatly to be desired that the preliminary review of elementary rules could altogether be dispensed with. I purpose hereafter to "condition" somewhat rigorously all candidates for admission who do not show real familiarity with such practical exercises as are contained, for instance, in the first four chapters of Hart's "Rhetoric and Composition," to require the making-up of such exercises, and to begin the critical reading of texts, as well as the practice of composition immediately. Nothing is more important than to teach such students as ours how to read; for, more than all rules of Rhetoric, the habit of careful reading will lead to accurate thinking, and therefore to clear writing; while a comparison of the different styles of the real masters of composition — a comparison which, whatever may be the imperfections of their school training, our students are quite mature enough to begin — is the only method by which life can be infused into the abstractions of the rhetorical manuals, and the surest way to correct the crudities in their own attempts at composition.

A course in English Literature is assigned me with the class of the Second Year. A "course in English Literature" is usually understood to mean a course of lectures embracing a general survey of English literary history; but such a survey must, from the necessity of the case, be extremely superficial, and can hardly do more than follow in the beaten track of printed "com-

[1] The Oxford "Clarendon Press Series"; The "Vest-Pocket Series" of Osgood & Co.; Harper's "Half-Hour Series."

pendiums" and "manuals." There is, to be sure, ample room for a diligent instructor who could afford to give his whole time to the subject, to make such a course highly instructive to students of sufficient maturity of thought; but such instruction should be the completion, not the beginning, of the course in Literature, and would find its appropriate place in the last year, where, at present, there is no room for it; neither, if there were, would the multiplicity of my present duties allow me sufficient leisure for the thought and study required to do it justice. A more appropriate course for second-year students is to give a practical example of the way in which such studies should be pursued, by confining the student's attention to a limited period, combining History and Literature together, as only two sides of the same subject, and continuing the critical reading of texts begun in the first year. A step further, however, may be taken, and the laboratory method of research may be imitated, by setting the student simple problems to work out in Political History, and in Literature and Criticism, with the help of my own and the City Library. This gives room for the only practice in advanced composition which is good for anything, the writing of papers on subjects which the student has actually investigated, and in which he feels a genuine interest. By a method of study of this kind, accompanied by a carefully prepared course of lessons from the instructor, both the inner and the outer life of a limited period, that is to say, the history of thought and the history of action, may be investigated in a tolerably satisfactory manner within the assigned limits, and the true nature of historical and literary study can be pretty well illustrated. A course so managed will be very sure to give birth to an interest in such intrinsically interesting subjects, even where that interest had been previously kept in abeyance by bad school teaching. Of this I have evidence in the application of portions of classes for leave to continue such studies voluntarily with me after the regular course is over.

It seems to me extremely important to the real success of

our school, that the cultivation of such tastes should be encouraged. The question is sometimes raised by superficial thinkers who pride themselves on being "practical" in their views of education, what place has the study of Belles Lettres, and even of History, in a course of study intended to prepare young men for a practical scientific profession. I observe with satisfaction that the uniform tenor of the discussions on education among practical scientific men themselves, is in favor of enlarging rather than narrowing the general literary element in their education.[1] Their almost unanimous opinion, drawn from practical experience, seems to accord with that of all the best theorists on the subject, that it needs an enlarged and many-sided culture of the intellectual powers to make a man successful even in the speciality to which he devotes his life, and that an engineer who is nothing but an engineer, cannot be, in the highest sense, even a good engineer. An English man of business[2] has recently made a striking plea for the culture of the *imagination* as a necessary element in any good preparation for business life, and has urged, with much ingenious and forcible illustration, the importance of historical and literary studies, as forming an essential part of the education of practical men. In the necessary absence of classical study from our course of instruction, the study of the English language and of English Literature and History, becomes from this point of view doubly important. In the sharp competition for pupils, which is beginning to arise between the various scientific schools of this country, those only will gain any permanent footing, or meet the approval of that minority of competent judges in the community on whose favorable verdict the success of such institutions must sooner or later depend, which have arranged their courses of study on really sound views as to what constitutes a good scientific liberal education. And it

[1] See particularly "Discussions on Technical Education, at the meeting of the Am. Inst. of Mining Engineers and the Am. Society of Civil Engineers," Easton, Pa., 1876.

[2] Mr. Goschen, M,P., the eminent London banker. See the Liverpool Daily Courier, Nov. 30, 1877.

will not do to say that the general element in such an education can be equally well represented by any and all kinds of general study, and that, beyond his strictly professional tasks, it is quite a matter of indifference whether the future engineer exercises his mental faculties on Greek or Hebrew, or any modern study which may be the prevailing educational fashion of the moment. In my judgment, the general studies of a professional man should be selected with quite as much care as his strictly technical studies, and it is not a matter of indifference whether the mental habits they create are in harmony or in antagonism with those generated by the professional part of his curriculum. Making allowance for peculiar idiosyncracies which may occasionally give a strong individual bent in the direction of some favorite bye-study, it may be said that the general element in the education of a young man destined for an active profession, should consist of those ingredients which will supplement the narrowness of his technical training in the direction of making him first a good citizen, next a good man of business, and next in the direction of opening to him a source of pure and elevated pleasure, by arousing in him a taste for what is beautiful in Literature and Art. The first object will be gained by the teaching of history and political science, the second by exercising his mind in the examination and discussion of economic subjects, and the last by opening to him the resources of one or more foreign literatures, while his taste is cultivated to appreciate all that is excellent in what is perhaps the richest of all modern literatures, his own. This surely is enough, and more than enough, for the surplus time and mental energy left from the demands of a rigid professional training in mathematical and physical science.

And in my judgment these non-professional studies should be conducted, — indeed in the present condition of our school they *must* be conducted, — in a different spirit and with different aims from those which must govern the professional. They should not be merely hard and disciplinary. The work should be done, as all intellectual work should be done, with care and

accuracy but it should be so conducted as to be a pleasurable relief rather than an additional burthen. The aim should be to implant tastes, to create new interests in subjects to which justice can be done only in the leisure and maturity of after life. The technical studies of our young men constitute a mental drill of the severest kind; but it is the foolishest and falsest of all narrow views of education the notion that it should be all drill. I have yearly cause to lament that this truth is not better understood when I see in our entrance examination-papers in History and Literature the barren results of so much honest but misdirected school labor.

There is at present but little room and less preparation for the systematic study of the moral and political sciences of which History and Literature are but the illustration. These would draw too largely upon the time and brains of students already exhausted by the demands of their professional work; but lighter courses in History and Literature may by judicious management be made a preparation for the more systematic prosecution of such studies in the leisure and maturity of after life. For one of the historical sciences, the Science of Government, a small opportunity is given in a short course on "Constitutional History" in the third year. I think it is very much to be desired that room should also be found in the course of study of all regular students for a part at least of the instruction which — in the absence of any regular provision — I have thus far volunteered to give the students in the department of Science and Literature in Political Economy. This is another of those studies, some knowledge of which is a necessary foundation to all profitable reading of History, and it seems almost an absurdity that in a practical school like ours some attention to this, one of the most important of all practical subjects, should not be required of all students.

It is very true, as I have already said, that our professional students can spare but a very inadequate portion of their time to these general studies. That is an evil for which there is but one remedy, a better preparation for admission, and I judge, as

one of the examiners, that it is an evil which is lessening year by year, and one which will lessen very rapidly as soon as better methods of elementary scientific preparation shall penetrate our High Schools. As soon as our young men bring to us that equipment of elementary mathematical and scientific knowledge which, with good training, they should possess at the age of seventeen, there will be far better opportunity for the higher English studies after their admission; and I think that time is not far distant. Instead therefore of narrowing the scope of the historical and literary instruction given in the Institute, I respectfully urge upon the Government the necessity for more liberal provision, in anticipation of a fast-approaching time when our students can afford to devote a larger share of attention to the element of general culture. That that general element should with us largely take the form of the study of History and Literature, and more particularly of the study of English History and the English Language and Literature seems to me beyond question.

I desire again earnestly to call the attention of the Government to the unsatisfactory condition of the so-called "Science and Literature" department. While it is never without just enough students to make my position a very laborious one, it yet adds nothing to the strength or the resources of the institution. I am confident that by a reorganization it might add to both. While we are not in a position, and it will never be our proper function to attempt to cover the wide field of general education embraced by our colleges, there is one special department of education quite germane to the purposes for which our institution was founded, which is nowhere well provided for, and which we might undertake with every prospect of success. I mean the preparation of young men for active business life by an education in the study of the modern languages, the experimental study of natural and physical science, and in English subjects, including History and Literature, the elements of Law and Political Science, Political Economy and Statistics, and Commercial and Industrial Geography. There is a large and

rapidly increasing class of young men in the community who, for various reasons, are not prepared, on the one hand, to invest their school years in the study of the ancient languages which is required for admission to our colleges, and on the other hand, have no taste or talent for engineering, or the other technical professions, but who yet do desire something beyond the education which our high schools give. By a not expensive addition to our teaching force, as at present organized, and by proper modifications in the course in "Science and Literature" — such modifications as shall give it a character as distinctly individual as the course in Chemistry, or the courses in Engineering — that course might be made to meet exactly this want. As at present arranged, it fully meets no want, and consequently attracts few students.

All which is respectfully submitted.

WM. P. ATKINSON,
Professor of English and History.

DEPARTMENT OF MODERN LANGUAGES.

President Runkle:—

DEAR SIR, Permit me to present herewith the report of the department of Modern Languages for the school year 1876–77.

FRENCH REQUIREMENT FOR ADMISSION.

The following shows the result of the last examination for admission, including that of the autumn of 1877.

1877.	
52	No. of students in First Year.
58	Average mark at Entrance Examination.
0	No. admitted without French.
41	No. admitted without conditions.
65	Average mark.
11	No. admitted with conditions.
31	Average mark.

By comparing the above with the results of previous years, as given in my last report, it appears that there continues to be a gradual improvement in the manner in which the requirement is fulfilled. There was still, however, such an inequality, that it was found necessary to form, of those who were behindhand, a class which has recited oftener and apart from the rest. The number in this Elementary class was nine throughout the year. The French required for admission is now, as indicated in the Annual Catalogue: "French grammar, through regu-

lar and irregular verbs, and the first two books of Voltaire's 'Charles XII' (about seventy pages)".

From blanks filled out at the examination, it appears that of the sixty-seven candidates for the First Year, fifty-eight stated that French was a regular study in the school where they prepared, and forty-two that Latin was, while forty-four reported that they had studied Latin.

WORK OF THE PAST YEAR.

The number of exercises per week in the department were thirty the first term, and twenty-seven the second. The following shows what has been read, and the amount.

FRENCH.

FIRST YEAR. Voltaire — "Charles XII," 80 pages. Tissandier — "L'eau," 172 pages. Töpfer — "Nouvelles Génevoises," 58 pages.

THIRD YEAR (Sc. and Lit.). Brueys — "L Avocat Patelin." Molière — "Les femmes savantes," "L'Étourdi," "Le médecin malgré lui."

FOURTH YEAR (first half). Mémoires — extracts from de Retz, St. Simon, 59 pages. Molière — Le bourgeois gentilhomme," 3 acts.

GERMAN.

SECOND YEAR. Whitney's Reader, 26 pages. Selections, 20 pages. Andersen's "Märchen," 16 pages.

THIRD YEAR. Whitney's Reader, 39 pages. Pfaff — "Das Wasser," 158 pages. Putliz —"Das Herz vergessen." Benedix — "Eigensinn."

FOURTH YEAR (Sc. and Lit.). Portions of Schiller's "Wallenstein."

Exercises in composition, written and oral, and on the forms and principles of the languages in question, have accompanied the above work in translation.

During the first term there was an optional class of eight students, that commenced the study of Spanish, using Sale's grammar, and reading twenty-five pages in Don Quijote. During the second term there was an optional class of six students, that attended a course of French readings, consisting of Victor Hugo — "Ernani," Beaumarchais — "Barbier de Séville," De Musset — "Un Caprice."

Following, are the examination papers at the Annual of the

First Year in French, and Third Year in German, with the average mark of the whole class on the same.

Respectfully submitted,
CHARLES P. OTIS.

[EXAMINATION PAPER OF THE FIRST YEAR AT THE ANNUAL.]

Number of students 27. Average mark 66.

1. Il se peut que les glaces amoncelées au pôle Nord amènent, comme le veut Agassiz, un mouvement subit dans l'axe de la terre, qui, par suite du changement de position de son centre de gravité, serait soumise à une terrible secousse, causant la mort de tout être inanimé, en déplaçant brusquement les océans. Il se peut que la terre, se refroidissant toujours par son rayonnement à travers l'espace, voie son épiderme, qui n'est en définitive qu'une croute figée par l'action du froid, augmenter d'épaisseur, et qu'un jour vienne où l'abaissement de la température soit tel, que l'eau n'existe plus sur notre sphère qu' à l'état de glace. Ajoutons toutefois que, si ces prévisions se réalisaient jamais, ce ne serait que dans une suite de siècles considérables.

1. Point out and explain the subjunctive forms in the above.

2. Explain the force of *se réalisaient*, and turn the sentence into any form it may take without a change of meaning.

3. Tell what you know about *en* in *en déplaçant*.

4. Give in full the present indic. of *peut*, the future of *voie*, the pres. subj. of *veut*, and the compound present of *se refroidissant*.

Render in French: The snow has been falling for several days, and the fields are covered with it; yet, although the cold is sharp,[1] it is not believed that the ice can bear.

[1] *perçant.*

II. En 1816, un paysan de Silésie, nommé Priessnitz, revenait de son champ, quand un cheval emporté le renverse, imprime ses fers sur son visage et lui brise deux côtes. Il n'y avait pas de médecin dans le petit village de Freiwaldau; Priessnitz veut se guérir lui même. Il fait peu à peu reprendre à ses côtes brisées leur direction première, en s'appuyant constamment la poitrine contre l'angle d'une chaise; pour tout bandage, il se sert d'un linge mouillé; il boit abondamment de l'eau froide, et bientôt il retourne à ses travaux.

— Quelques années après, le paysan Priessnitz fonde un vaste établissement, où de tous les points du globe accourent une foule de malades, venant demander à l'art empirique la guérison que leur a refusée la médicine.

1. Analyse the last sentence, beginning with *guérison.*

2. Point out instances of imperfect and compound of present in the above, and explain the relation of those tenses to the preterit, respectively.

3. Explain the form of the participle *refusée*, and make a sentence which requires it to be written *refusé.*

4. Give the literal meaning of *lui brise deux côtes, en s'appuyant la poitrine*, and give the rule for such forms.

Render in French: In Greece[1] there was a fountain of which it was said that those who had bathed in it were cured of their love. It is a virtue[2] that it has since lost.

[1] *Grèce.* [2] *la vertu.*

III. Et si vient la pluie, croyez-vous que je perde mon temps? Jamais je n'ai tant à faire. Voilà mille petites rivières qui se rendent au gros ruisseau, lequel s'emplit, se gonfle, mugit, entraînant dans sa course des débris que j'accompagne chacun dans ses bonds avec un merveilleux intérêt. Ou bien quelque vieux pot cassé, ralliant ces fragments derrière son large ventre, entreprend d'arrêter la fureur du torrent.

— C'était la première fois que, la voyant de près, je pouvais me repaître du charme que je trouvais en elle. Que ne puis-je le répandre en ces lignes et la peindre comme elle m'apparaissait. Et encore semblait il que la bibliothèque de mon oncle Tom lui fût comme un cadre merveilleux qui rehaussait son éclatante beauté. Sur les rayons poudreux, ces livres vénérables, représentant la suite des âges, ce parfum de vétusté, ce silence de l'étude, et, au milieu, cette jeune plante toute de fraîcheur et de vie . . . Ce sont choses qui ne se peuvent enclore dans des mots.

1. Explains the forms *perde, s'emplit, fût.*

2. Point out the relative pronouns in the above, commenting on the form of each.

3. In *ce sont choses qui*, etc., why is not *ce* in the plural? Explain that word.

4. Give the principal parts of all irregular verbs in the passage above.

Render in French: This is the house in which we used to live and that I have so often described to you. My uncle's was situated on the same street.

Write a few lines in French about each of the following topics: *Les vendanges. Les pommes de terre. Les bateaux à vapeur.*

IV. *Passage not read before.* Qui trouverait dans une île déserte et inconnue à tous les hommes une belle statue de marbre, dirait aussitôt: Sans doute il y a eu ici autrefois des hommes; je reconnais la main d'un

habile sculpteur; j'admire avec quelle délicatesse il a su proportionner tous les membres de ce corps, pour leur donner tant de beauté, de grâce, de majesté, de vie, de tendresse, de mouvement et d'action. Que répondrait un homme, si quelqu' un s'avisait de lui dire: Non, un sculpteur ne fit jamais cette statue. Elle est faite, il est vrai, selon le goût le plus exquis, et dans les règles de la perfection, mais c'est le hasard tout seul qui l'a faite. Parmi tant de morceaux de marbre, il y en a eu un qui s'est formé ainsi de lui-même; les pluies et les vents l'ont détaché de la montagne; un orage très-violent l'a jeté tout droit sur ce piedestal qui s'était préparé de lui-même dans cette place. FÉNELON.

FIRST YEAR. MAY, 1877.

[EXAMINATION PAPER OF THE THIRD YEAR AT THE ANNUAL.]

Number of students, 24. Average mark, 59.

I. Während des Winters lagen die Kreuzfahrer zerſtreut zwiſchen Philadelphia und Konſtantinopel; allmälig zog ſie Friedrich aber immer näher an die Hauptſtadt hinan, ließ die Befeſtigungen von Philadelphia zerſtören, und gab den Geſandten der Königin Sibylle von Jeruſalem und des walachiſchen Fürſten Kolopetros Gehör. Jene behaupteten (obgleich ohne weitere Beweiſe), die Griechen wären geſonnen, alle Kreuzfahrer durch Wein und Mehl zu vergiften, und Kolopetros verſprach ein Hülfsheer von 40,000 Mann, wenn Friedrich, der römiſche Kaiſer, ſich auch die griechiſche Krone aufſetzen wolle. Noch einmal wies der beſonnene Held, um ſeiner urſprünglichen Zwecke willen, dieſe einladenden Anträge zurück; aber ſchwerlich hätte er ſich länger allen Launen der Griechen unterworfen. *von Raumer.*

II. Von allen Seiten drangen jetzt die Türken auf die Pilger ein, und die Größe der Gefahr preßte ſelbſt dem ſtandhaften Kaiſer den Wunſch ab: „er wolle gern jede andere Noth ertragen, wenn nur das Heer ungefährdet in Antiochien wäre.“ Als aber die Seinen wirklich anfingen zu weichen, rief der Greis mit lauter Stimme und durch ſeinen Heldenmuth wunderbar verjüngt: „Warum zögert ihr? Weshalb ſeid ihr niedergeſchlagen? Gottlob daß die Feinde endlich eine Schlacht wagen! Um den Himmel mit eurem Blute zu gewinnen, verließt ihr das Vaterland; jetzt iſt die rechte Zeit, folgt mir, Chriſtus ſiegt, Chriſtus herrſcht!“ Mit dieſen Worten ſprengte Friedrich in die Feinde, es folgten ihm ſeine Mannen, und in demſelben Augenblicke gewahrte man die chriſtlichen Fahnen auf den Thürmen von Ikonium. *von Raumer.*

III. a. Seine Ufer und ſein Grund beſtehen aus kaltem Waſſer, während ſeine Strömung warm iſt. Der Golf von Mexiko iſt ſeine Quelle, und ſeine Mündung liegt in den arktiſchen Meeren. Es iſt der Golfſtrom. Es giebt in der Welt keine zweite Waſſerfluth, die ihm an majeſtätiſcher Größe gleich käme. * * *

b. An Waſſerfülle ſtehen jedenfalls alle dem Amazonenſtrome nach, wie er auch der Ausbreitung ſeines Stromgebietes nach alle anderen weit hinter ſich läßt, indem er einen Flächenraum von 112,000 q. M., alſo ungefähr die zehnfache Ausdehnung von Deutſchland einnimmt.

c. Auch die reinſte Quelle enthält mineraliſche Beſtandtheile, welche das durch die Sonnenwärme aus dem Meere diſtillirte und als Regen herniederkommende Waſſer auf ſeinem unterirdiſchen Laufe aus der Erdrinde ausgezogen.

d. Auch aus heißen Quellen ſetzen ſich oft ſehr beträchtliche Maſſen von kohlenſaurem Kalke ab. Es geſchieht dies noch raſcher, als aus kaltem Waſſer, weil aus warmem die zur Löſung des kohlenſauren Kalkes nöthige Kohlenſäure viel raſcher entweicht. Eines der bekannteſten Beiſpiele für ſolche Abſätze liefert der karlsbader Sprudel, der eine ungeheure Menge von verſchieden gefärbten Maſſen, unter dem Namen Sprudelſteine, vielfach verſchliffen und verarbeitet, abſetzt. *Pfaff.*

IV. a. Analyze in full the following, stating in the case of each, as also of the parts composing it, whether it be derived or compound: Kreuzfahrer, Befeſtigung, behaupten, Antrag, Heldenmuth, beträchtlich, Unentſchloſſenheit.

b. What is the difference between compound and derived words? When a noun is the first part of a compound word, what variations in its form may there be? What are the two modes of forming derived words; the relative frequency of their use? What is the force of the inseparable prefixes ver, and zer?

c. Give the English *historically* connected with the words ziehen, fahren, bringen, fangen, ſchlagen, Zeit, Theil; with the suffixes -ſchaft, and -thum.

V. a. Case and construction of Befeſtigungen, Kaiſer, ſich (I); Ausbreitung (III, b); welche (III, c)? What is the difference in the use of während in I and III, a? What is the difference in *meaning* and *construction* between von verſchieden gefärbten Maſſen (III, d) and von verſchiedenen gefärbten Maſſen?

b. To what class of the subjunctive belong wären (geſonnen), hätte unterworfen (I); wolle, wäre (II); käme (III, a)? What is noticeable in the *tense* of wären (geſonnen)? What is the difference between the force of käme and the indicative (as would be used in English)?

c. Principal parts of lagen, geſonnen (I); weichen (II); verſchliffen (III, d). Is unterworfen (I) a separable or inseparable verb, and why? How does ſeid ihr niedergeſchlagen (II) differ in *form* and *meaning* from habt ihr niedergeſchlagen?

VI. a. LEIPZIC, March 24.

Dear Sir: — Your letter was received last week. I beg pardon for not answering the same at once, but was prevented by pressing business.[1] The books of which you speak we have on hand. We will sell them to you at a discount of ten per cent. If you wish the same, please inform[2] me, and I shall take pleasure in filling your order. Yours respectfully.

[1]dringende Geſchäfte. [2]benachrichtigen.

b. I overheard[1] this morning our Henry requesting[2] Elizabeth to say: "Heaven be thanked, the table is set," and falling[3] into a violent[4] strife with her when she would not do so. Laughing, I related that to my wife; with flattery[5] I said to her that she would not be so obstinate, and, in jest, begged her to speak those words. She however refused[6] with such decided obstinacy, with such striking[7] stubbornness, that we had a serious altercation.[8]

[1]belauſchen. [2]verlangen; who requested. [3]gerathen. [4]heftig. [5]ſchmeicheln. [6]ſich weigern. [7]auffallend. [8]Wortwechſel.

c. Write in German the second stanza of „Die Lorelei." Schreibe kurze Aufſätze über die folgenden Gegenſtände: „Die Vögel im Winter;" „Die Windmühlen."

VII. (Passage not read.) Gehen wir noch einmal auf den Vergleich des Auges mit der *Camera obscura* zurück, ſo fällt uns noch ein beſonderer Vorzug des Auges auf, den daſſelbe vor jener voraus hat. Er beſteht darin, daß die Hinterwand des Auges kugelförmig gewölbt iſt, während in der *Camera* die matte Scheibe,[1] welche das Bild auffängt, eben iſt. Dadurch erhält aber das Auge zwei weſentliche Vortheile, die jedem leicht auffallen werden, der einmal das Bild einer *Camera* betrachtet hat. *Bernstein.*

[1] disk.

LOWELL FREE COURSES FOR 1876–77.

General Chemistry. Twenty-four laboratory exercises.
Qualitative Analysis. Twenty-four laboratory exercises.

President Runkle ; —

DEAR SIR : — The Lowell Course in Chemistry the present year, although conducted on the same plan as in previous years, has been unusually satisfactory. Many of the applications were made in person, and were from those having a strong desire to avail themselves of the opportunities offered, and the number of really earnest workers seemed to me to be larger than usual. The entire number of persons attending the exercises was fifty-four ; the largest number at any one time members of the two classes was forty-eight ; the average attendance was 36.5. This average may seem rather small, but several circumstances account for it : the weather on two of the days was so very severe that many were prevented from coming, and the school holidays coming during the course caused the absence of many of the teachers who were at the time out of town. The smallest attendance was twenty-seven ; the largest forty-one.

The following statistics may be of interest : —

Number of students in General Chemistry	34
Number of students in Qualitative Analysis	20
Number of male students	32
Number of female students	22

Occupations as far as recorded:

Teachers	26
Physicians	1
Pharmacists	10
Engaged in other business	8
Unknown and Students	9
Total	54

Yours, very respectfully,
WM. RIPLEY NICHOLS.

Elementary Geology. Eighteen lectures.

These lectures began by defining the general principles of dynamical and historical geology, and then proceeded to consider the history of the great geological divisions, as illustrated by the rocks of North America, regard being had both to their geographical relations and to their economic mineralogy.

T. STERRY HUNT.

The Philosophy of Government. Eighteen lectures.

This course was attended by some fifty persons, the majority being men, and a large part of them students of law, or young lawyers. The following is an outline of the topics: —

Lecture I. The Nature of the State: — It is not a contingent combination of individuals, resulting from (*a*) the pressure of external evils, or (*b*) the accident of descent or juxtaposition.

Lect. II. The Nature of the State: — It is not a voluntary organization of individuals for ends merely special, either (*a*) the maintenance of private rights, or (*b*) the promotion of Economics.

Lect. III. The Nature of the State: — It is the investiture of Rational Man with institutions, — the organization of Universal Personality considered in its progressive entirety.

Lect. IV. The Foundations of Sovereignty, as given in the Logical Origin of the State: — Theory of the "Social Contract"; sovereignty not from it.

Lect. V. The Foundations of Sovereignty: — Theories of the "Natural" Origin of the State; it is not (*a*) from Conquest, or other forms of Force; nor (*b*) from the Family; nor (*c*) from the Collective Will of the People.

Lect. VI. The Foundations of Sovereignty: — Theory of Divine Right; the State is founded in Human Nature, *i. e.*, comes from God.

Lect. VII. The Foundation of Rights: — The State is their only sufficient basis.

Lect. VIII. The Nature of Rights and, especially, of Citizenship: — Rights are simply conditions of Personality legalized, and their possession is conditioned upon the actualization of Personality; Citizenship is investiture with Rational Freedom, *i. e.*, with Obedience to Law from Conviction.

Lect. IX. The extent of the State's realm in Human Life, (*a*) by the Social Process, (*b*) by Formal Administration.

Lect. X. The function of the State in Education, Morals, and Religion.

Lect. XI. The Form of the State, as distinguished from its Substance; the Medium of the Form, as distinguished from its Sovereignty. The two main Forms, — the Realm and the Commonwealth.

Lect. XII. The Liability of the Realm to antagonize the State, (*a*) as Autocracy, (*b*) as Empire, Tyranny, or Cæsarism, (*c*) as Oligarchy, (*d*) as Democracy.

Lect. XIII. The nature of Constitutions; the Hereditary Principle as the basis of distinguishing the Kingdom from the Republic.

Lect. XIV. The ultimate Distinct Functions in the State.

Lect. XV. The true nature of Representative Government: the Representative stands for the Civil Idea, not for Constituents.

Lect. XVI. The basis of Suffrage: — Three questions: (1) What warrants the vote as a right? (2) To whom does the right belong? (3) By what polity shall the right be kept with those to whom alone it belongs?

Lect. XVII. The Statutes and the "Higher Law."

Lect. XVIII. The Literature of Political Philosophy.

GEO. H. HOWISON.

Department of Mechanics. Eighteen Lectures.

President J. D. Runkle: —

DEAR SIR: — Before determining upon the subjects of the separate lectures in the course on Practical Mechanics, given by me in the autumn of 1876, I consulted a number of gentlemen who conduct manufacturing establishments in this vicinity, and who have large numbers of workmen under their charge, so that I might make use of the light thus obtained to select such subjects as seem most suitable for mechanics, for whom the lectures were specially intended. I received from many of these gentlemen not only advice, but also the loan of specimens and working drawings. I have to thank, especially, Mr. Boyd, Engineer of the Atlantic Works, E. Boston, Mr. Leach, General Manager of the Hinckley Locomotive Works, Mr. Fairbairn of the Hartford Insurance Co., and Messrs. Richards and Crooker of the Bay State Iron Works. I also took pains to inform the Superintendents of a number of shops of the projected lectures, and to request them to call the attention of their employees to them. The largest number present at any one lecture was eighty, the average attendance being twenty-five or thirty. The subjects actually selected were as follows:

I. Strength of shells, tubes, flat and cambered ends of Steam Boilers, Copper and Cast Iron as used in Boiler Making.
II. Wrought Iron and Steel.
III. Riveting and Welding.
IV. Description of main types of Steam Boilers and essential differences.
V. Construction of Boilers.
VI. Furnaces and Boiler Setting.
VII. Furnace and Boiler Fittings.
VIII. Wear and Tear and Incrustation.
IX. Boiler Explosions.
X. Boiler Power and Combustion of Fuel.
XI. Steam Engine Indicator.
XII. " " "
XIII. Governors.
XIV. "

XV. Belting. — Materials used — Forms of Pulleys — Crowning of Pulleys — Lateral Stiffness of Belt — Engaging and Disengaging — Fast and Loose Pulley — Quarter Twist — Guide Pulleys, etc.

XVI. Velocity ratio in Belting — Speed Cones — Eccentric Pulleys — Wire ropes.

XVII. Strength of, and Power transmitted by Belts and Wire ropes.

XVIII. " " " " " " "

Very Respectfully,

GAETANO LANZA.

ABSTRACTS OF THESES PRESENTED BY GRADUATES OF 1876-77.

DEPARTMENT OF CIVIL ENGINEERING.

The Central Avenue Bridge, Dorchester, Mass. Abstract by the author, H. H. Carter.

This bridge, which is built in two spans of 94 ft., and 63 ft. 6 in. respectively, crosses the Neponset River at Central Avenue, Dorchester, Mass. Each span consists of six wrought iron, single intersection, lattice girders, placed 8 ft. 4 in. apart on centres; the girders being connected at the top and bottom chords by lateral bracing, and at the ends and intermediate points by vertical cross bracing. The girders in both spans are 6 ft. 5 in. in depth, resting at their abutment ends on wrought iron rollers, and at their pier ends on cast iron bearing plates.

Both chords are of T-shaped section, built up from wrought iron plates and angle irons. The web members consist of angle irons riveted to the vertical web plates of the chords, and also to each other at intersection points. The floor timbers rest on the top chords of the girders, and are of yellow pine, fifteen inches deep at the centre of the roadway, and twelve inches deep at the sidewalk curbs. Alternate floor timbers project over the outside girders in order to support the sidewalk, and are six inches in width, the remaining timbers being four inches in width. The roadway planking is in two courses; the lower course is of yellow pine four inches thick, spiked to

the floor timbers; the upper course is of spruce two inches thick, spiked to the lower course.

The long span was taken for detailed investigation, and the stresses arising from a live load of 100 lbs. per sq. ft. and a dead load of 50 lbs. per sq. ft. were calculated; also the stresses produced by a 20 ton wagon placed in various positions upon the bridge.

The maximum stresses in the different parts of the girder having been found, the necessary dimensions have been calculated and compared with the actual dimensions used in the construction of the bridge. Accompanying the description and calculation of the bridge are two sheets of drawings, showing the details of construction and the manner of connecting the various parts.

Sea Walls of South Boston Flats. Abstract by the author, Martin Gay.

Accompanying this thesis are two sheets of drawings, one showing the location of the walls, and their relation to the harbor and wharves of Boston, and the other showing on a larger scale the shape of the dock which the walls enclose, and sections of the different kinds of wall used.

I have explained that this project was intended only as an improvement to the navigation of the harbor, and the reasons for its being undertaken, and that it was finally extended into a scheme for reclaiming the useless flats of the Commonwealth; also the methods of filling the flats with the material dredged from the harbor.

Next, I have described the form and materials, and have calculated in turn each wall; investigating first, whether the wall of itself is strong enough to resist the forces acting upon it, and second, if the foundation upon which the wall rests will bear the load put upon it.

The Lowell Water Works. By Joseph P. Gray.

(Abstract not received.)

The Charles River Bridge at Newton Upper Falls. Abstract by the author, Edward Grover.

The subject was treated under the following different headings:

I. The Location and general description. II. Materials and Construction; with explanation of drawings. III. Calculation. Strength and Stability. IV. The Centering.

The Sudbury River Aqueduct for bringing an additional supply of water to Boston was begun in July 1875, and at the time of writing was in different stages of construction. The line from Farm Pond in Framingham to Chestnut Hill reservoir is 15.61 miles long, and is an interesting example of construction in swamp and quicksand, of rock and earth tunnelling, and of cuttings and embankments.

The most important structure on the line is the bridge which carries the conduit over the valley of the Charles River at Newton Upper Falls. This bridge is 475 ft. long between the terminal chambers. At the westerly end is a semi-circular arch of 37 ft. span, partly cut off by the slope of the hill which is quite steep. Next is a segmental arch of 130 ft. span and about 45 ft. rise, radius 69 ft. Then there are on the east side of the river, four semi-circular arches of 37 ft. span and lastly, a flat arch having a span of 28 ft. over Ellis St., a town way. In making the surveys there were two schemes for crossing the river under consideration; namely, by a bridge as located and by means of a siphon about a mile from the former. The cost was nearly the same for each and the Water Board decided to build the bridge. The river at this point is quite narrow, a little over 100 ft. wide and the slopes of the valley, especially the westerly bank, being abrupt and the river bed and banks of firm rock, making a good foundation for the piers and abutments. The springing of the large arch is considerably above

the water-level which latter varies but slightly during the year; accordingly there is no obstruction of the water way. The width of the bridge just below the conduit is 18 ft., the face walls having a straight batter of one in twenty-four, except for the great arch which has a curved batter, being the curve of presures. It is the largest stone bridge in the country, with one exception, and is a model of strength and beauty.

The construction is next described in the following order. (1) Foundations, (2) Piers, (3) Voussoirs, (4) External Spandrel walls, (5) Interior Spandrel, filling, &c., (6) The Conduit, dimensions and construction, (7) Terminal chambers, manholes, (8) Approaches, including a description of the materials and their composition and a description of the accompanying drawings.

The foundations consist either of the natural rock or of large blocks of granite laid at such depth as to be sufficiently firm. The steep western slope and the river bed are composed of a compact granitic rock. The western slope was prepared by removing the soil and loose rock and dressing the solid rock with the hammer to plane surfaces perpendicular to the thrust of the arch at the springing, and level or vertical elsewhere, thus forming sets of steps. The bed of the river was prepared as follows to receive the vertical timbers which supported the centring: The mud was removed and blocks of stone laid on the natural rock; levels were then taken at each point of support and the top of those blocks were made as nearly level as possible; timbers were next laid horizontally, the lower surfaces being cut to fit the stone so as to bring the upper surfaces exactly level. The slope on the easterly shore was neither so steep nor so rocky, and the earth was simply excavated a few feet to receive the large rectangular blocks of stone laid as above mentioned, each block being smaller than the one below it to distribute the pressure over a larger area.

The piers are composed of very large rectangular blocks of ashlar with dressed beds, builds, and vertical joints and well bonded together. The faces are built with a batter and the

caps are of a little lighter colored stone. The foundations, piers and centring having been completed the arches were begun and carried up, keeping at the same height on each side, so as to keep the load on the centring symmetrical. The keystone has a depth of five feet and the springing stones a depth of six ft. for the great arch.

The voussoirs are hammered smooth, the intrados to the curve and the ring and coursing joints to plane surfaces, leaving no cavities. In the large arch the faces of the voussoirs are bounded by neat lines three inches distant from the plane of the spandrel wall, and the projection is chamfered off at 45°. The voussoirs of the roadway are also chamfered, the projection being two inches.

The exterior spandrel walls are twenty inches thick at the top and increase to twenty-four inches at the springing of the small arches, below which they are twenty-four inches. The face stones are quarry faced and a certain part of the walls are of split stone, all well bonded together. Between the two exterior spandrel walls are two walls of brick laid in mortar. These are eight inches thick and are tied together and to the exterior walls by long bond-stones. They are also covered on top with split stone which supports the conduit. Near the top of these walls, the spaces between are arched over, thus forming continuous passages between the arches by which access may be had under the conduit. These passages are lighted and ventilated by narrow openings in the spandrel under the lower string course. Part of the space between the spandrels is filled with cement concrete. Great care was taken in the designing and construction to make the conduit as nearly as possible water-tight, and also to provide for the thorough drainage of any water which might leak through. The floor of the passages above mentioned is cemented, and then in order that any percolation may not effect the spandrel walls the water is conducted over the concrete filling, which is covered with a coating of coal-tar concrete, to gutters in or near the centre of the piers and runs out at "weeping holes" at the springing of

the arches. The cross section of the bridge is like that of one of the bridges on the Croton Aqueduct in New York.

The conduit is of good size, much larger than the old Cochituate conduit, the sectional area being equivalent to a circular section of $8\frac{1}{2}$ ft. diam. It is estimated that it will deliver at the rate of seventy millions of gallons in twenty-four hours. In the thesis was a sketch of the section showing the curves of the inside, etc., as also a sketch of the Croton aqueduct, with which it was compared. The manner of building the conduit on forms was described. The whole of the curved brick lining was coated both inside and outside with coal-tar concrete, and when finished, an additional coating of pure Portland cement one-fourth inch thick was applied over the inside. The side walls outside the curved brick lining are of brick having an air space running through the centre of each. These walls are covered with a coping of smooth cut granite. This coping or upper string course together with the lower string course of similar stones just below the conduit are a great addition to the architectural beauty of the bridge. The side walls of the conduit are covered with these coping stones between which and the top of the covering arch the filling is of cement concrete with a layer of coal-tar concrete. This with the coping forms a water-tight roof and a splendid promenade for moonlight nights. There is an ornamental iron fence over the whole length. The exterior of the conduit walls is of face brick formed into panels which gives a very pleasing effect.

The terminal chambers are somewhat different in construction and contain a manhole in each for access to the interior of the conduit. The internal passages of the bridge are entered by a trap-door at the foot of the roadway arch. The bridge is terminated by a series of steps, of the smooth light granite like the coping, which will prevent the bridge being used as a drive. The accompanying drawings consist of a side elevation and different sections, cross and longitudinal, at different points through the large and small arches. Also plan elevation, and sections of the terminal chambers.

Calculation. In designing an arch of masonry, many points have to be considered in order to assure sufficient strength and stability. The load to be supported is generally known, to which, having assumed the form, we have to proportion the rise and span which are both somewhat limited, and also to determine the thickness of the arch-ring both at crown and at springing, the height to which the backing must be carried, etc. In this class of structures there is almost always some similar work already in existence which may be imitated or modified to suit the requirements, but we ought to know, especially in any new case when we may not obtain from experience and analogy the necessary information, exactly what are the actions which are produced in an arch by different manners of loading, etc. In other words we want to know the form of the curve of pressures. This we may do by means of a graphical construction, or by analytical formulæ we may obtain the point in the arch ring where the line of pressures passes near or beyond the edge of the voussoirs. In the present case where the relation between the form of the arch and the load could not be easily expressed, the point of rupture and maximum horizontal thrust was found graphically according to the method of Rankine. The method of Dr. Scheffer was also used and compared with Rankine.

The Centring. In calculating the greatest normal pressure that can come on any segment of the arch, with exactness, friction ought to be taken into account, as also the fact that the normal pressure of any voussoir upon the centring is decreased the more the arch stones are laid above it, since the normal component of the tangential thrust due to the voussoirs above acts outward and opposite to the normal component of the weight of the voussoirs considered. According to Rankine friction should be disregarded, as the action of the voussoirs when completely laid to the keystone is nearly the same whether friction acts or not. But what is required is to find the greatest normal thrust on any one segment which would not occur when the whole arch was complete. However for practical purposes,

neglecting the friction, the calculations, as Rankine says, would err on the safe side. Then the only way to proceed appears to find the normal thrust for each stone separately which process must be omitted in the abstract. A drawing of the centring of the large arch was inserted in the body of the thesis. The whole cost of the bridge was $174,105.75.

The Double Lattice Parker Iron Bridge across the Merrimack River at Lowell. Abstract by the author, Richard A. Hale.

A brief sketch of the old bridge and reasons for changing are given, and then a description of the abutments and new bridge.

The present bridge consists of two iron Parker girders, each of about 150 ft. span, 40 ft. wide, and 20 ft. in height in the centre, with curved upper chords and horizontal lower chords. The girders are commonly known by the name of "Hog-back." One span was taken for discussion. As no drawings were available, complete measurements were made of the bridge, from which the weight of the structure was calculated.

From this data the dead load was taken as 20 lbs. per square foot, and the live load as 60 lbs. per square foot. The methods of obtaining the maximum stresses in the chords, diagonals and uprights, were explained, and the maximum stresses of all the parts given in tabular form. The sectional amount of material in each piece was compared with the sectional amount required to resist the stress, and the strength of all the rivet and pin connections were calculated. The cross girder for sustaining the road-way is an iron Pratt truss, with projecting ends for sidewalks. The method of finding the maximum stresses in all of the parts were given, and the stresses were arranged in tabular form, together with the sectional areas required, and the actual sectional area. The strength of the connections were also calculated. In the calculation for the floor stringers, a concentrated load of twelve tons was taken on each stringer, and the resistance computed. For sway bracing the wind was

considered as acting uniformly on 500 square feet with a force of 20 lbs. per square foot, and the strength of the rods calculated.

Two drawings were made, one containing the plan and elevation of the bridge, and the second containing the details and connections on an enlarged scale.

Highway Bridge across the Merrimack River, between Groveland and Haverhill. Abstract by the author, George W. Kittredge.

The thesis begins with a short history of the unsuccessful attempts in 1834, 1835 and 1836 to obtain a charter to build a bridge where the present one stands.

The bridge, as erected, consists of six spans of 124 ft. each, besides a draw span of 48 ft. It is a bowstring girder in form, and was built by the King Bridge and Iron Manufacturing Company of Cleveland, Ohio. The different parts of the structure are next described in the following order: (1) The cribs upon which the piers rest; (2) The piers; (3) The abutments and wing-walls; (4) The superstructure. The calculations are made and explained upon the supposition that when a bowstring girder is uniformly loaded over its entire length, the load is transmitted directly to the arch through the verticals. A table accompanying the calculations gives the total load, the required sectional area, the actual sectional area, the safe intensity of stress and the actual intensity of stress on each of the pieces calculated. In the conclusion are set forth some of the greatest objections to the structure, and the manner in which they might have been obviated to a certain extent.

The New Bedford Water Works. Abstract by the author, C. F. Lawton.

The advantages furnished by an abundant supply of fresh water, on the score both of health and economy, are first spoken of. I have then entered into many general questions of

water supply — the portion of rain-fall available, the measurement of the same, the quality of water, methods of analysis, etc. I have then given a short history of the New Bedford Water Works, and noticed particularly the questions of which a general discussion has previously been given. The construction of many parts of the works, such as the dams, waste-weirs, aqueduct, etc., has been explained minutely, and has been accompanied by drawings.

The discussion of the pumping engines has been left, as being more suitable for the mechanical engineer; and the subject of the distribution of the water requires too much space to be treated of in this thesis.

The Lawrence Water Works. Abstract by the author, B. C. Mudge.

The supply of water to large towns has become a subject of so great importance, and involves problems of so extensive and complicated a nature that the best skill and attention of scientists and practical engineers have been called into requisition in its treatment.

In supplying this indispensable element of health and comfort to a large city, water is drawn, in many cases, many miles distant; it has to be purified and filtered for domestic use; elevated often to a height of hundreds of feet above its original level, and finally distributed through nearly every street, and into the interior of almost every house. It will therefore be easily conceived that the operations accomplishing these objects require in arrangement and adaptation no small degree of scientific and technical skill.

A short account of the earliest instances of a water supply to cities, other than by natural means, particularly those of Jerusalem and Rome, together with a mention of the Assyrian, Persian and Egyptian peculiarities relating thereto, served to introduce the subject. The hygienic necessity of a disjunction of the sewage waste and water supply, with some facts con

nected with the pollution of the water of the Thames, was urged from many standpoints.

The various sources and qualities, modes of conducting, purifying, pumping, storing and distributing the water, were the chief topics for consideration, each subject receiving separately its due amount of attention. The quantity, quality and methods of rendering the relative values of their determinations in a given district serviceable, were presented. Granting these principles relating to water supplies in general to be in the main correct, a description of the Lawrence Water Works, showing how far they conform thereto, practically illustrating many of the facts adopted, was undertaken, from a knowledge derived by a personal study of the drawings and works themselves.

With the Merrimac River as the source of supply, there seemed to be no limitation to the amount to be obtained, and in the year 1873 the first steps were taken to prosecute the work.

DESCRIPTION.

There is an inlet pipe admitting water directly from the river to the wells of the pumping station, one hundred and seventy feet long, constructed partly of brick masonry and cast iron pipes thirty-six inches in diameter. A filtering gallery was introduced along the bank of the river to provide, in certain seasons of the year, a supply of filtered water whenever the water of the river should become turbid. This is of granite foundation, with an arch of brick masonry. The pumping engines were built by S. P. Morris & Co., from the designs of E. D. Leavitt, Jr., of Cambridge, Mass. They are overhead beam engines, with compound cylinders. The force main is a line of cast iron pipes thirty inches in diameter, extending through a tunnel of brick masonry nine hundred feet in length to the reservoir.

The reservoir is rectangular in form, seven hundred and thirty feet long, four hundred and eleven feet wide, with a division embankment, and capable of containing 40,000,000

gallons when filled to high water mark. Upon this division wall is an over-fall, for the purpose of aerating the water. One peculiar and very valuable advantage these works possess above most others is, that both systems of distribution can be employed at will; that of pumping directly into the street mains the water to be delivered finally into the reservoir; also that of pumping directly into the reservoir through the force main, thence to be delivered to the inhabitants.

The Newton Water Works. Abstract by the author, A. L. Plimpton.

In this thesis the general questions, which always have to be considered before establishing a system of water works, are discussed in the first pages in their important points. They are, namely, the questions of quantity, quality and the most available source or sources of supply. At the same time these questions are applied to the particular case of Newton. Its most available source was the Charles River, which now supplies the city.

In regard to economy, the plan adopted by Newton was the Reservoir and Pumping System, or Gravity Plan.

After these matters, a general description of the works is given. They consist of the Filtering Basin, the Pumping Station, the Reservoir, together with the various pipes and conduits which connect the same, and lastly the Distributing Pipes.

THE FILTERING BASIN.

It is about 1000 feet long, the cross section being 70 feet on top and 10 feet at the bottom. It follows the general direction of the river, and will probably be extended up the river before long.

An iron pipe connects the basin with the pumping station. The plan of the pumping wells is shown by a drawing. The Worthington Pumping Engine is used, and the water has to be lifted about 170 feet.

THE RESERVOIR.

This is of irregular form adapted to its position on a side-hill The embankments are well built, and are covered with a slope wall of blocks of granite on the inner side. The specifications for the work throughout were very strict and were followed very closely.

The reservoir is partly in excavation and partly in embankment, it being so placed as to make the quantity of material removed about equal to that required for the embankments.

In excavating, the method of "Falls" was used. The gain of this, in regard to the amount of work required, over the old way of working it all with picks, is discussed; and assuming a certain size for the fall which is about that usually taken, the result shows that it does not require quite half the time, with the same amount of labor, to completely break it up ready for the shovellers.

In obtaining the capacity of the reservoir, the area of the bottom was calculated by the method of coördinates. I then found the contents, assuming the sides to rise vertically. But as the sides have a slope of $1\frac{1}{2}$ to 1, there is an additional amount to be taken in, whose cross section is a triangle. As this cross section is constant I used the Theorem of Pappus. The reservoir holds about 14,600,000 gallons.

THE GATE CHAMBER.

The arrangement of the pipes in the gate chamber is such, that while the engine is working, the supply in the distributing pipes is obtained without its passing into the reservoir first. But when it is not working, the supply is again taken from the reservoir. To effect this result a single pipe serves both as the inlet and outlet of the reservoir, arranged with automatic valves.

Iron pipes were used throughout, and the methods for ascertaining the necessary thickness is discussed in the thesis. It is a matter about which there is considerable variance of opinion and many different formulæ are given. The thickness, of

course, depends upon the head and the desired diameter. We find these involved in most of the formulæ and also various constants determined by experiment. Rankine's formulæ are the two following.

$$\left.\begin{aligned} t &= \sqrt{\frac{D}{48}} \\ t &= \frac{HD}{12{,}000} \end{aligned}\right\} \text{ the largest result to be used.}$$

It is found that either of these give a very low result. The formula adopted for the Newton Water Works is the following

$$t = (.00008\ H\ D + .01D + .36) \text{ inches.}$$

H = the head in feet. D = the diameter in inches. As an illustration of the different results obtained by using the above formulæ I give the following. For a 12″ pipe with a head of 200 ft, the Newton Formula gives t = .67 of an inch. Rankine's Formulæ gives t = .50 of an inch. The very systematic way of tabulating the subject adopted at Newton, I have shown in the thesis.

Oftentimes a pipe will be thicker than is necessary because it is better not to have too many classes, and rather than for a small amount of pipe to have a different size, it is placed with the size next thicker.

Design for an Iron Railway Bridge, with a consideration of the Principles determining the Design. Abstract by the Author, George F. Swain.

The purpose of this thesis is to design an iron railway bridge, and to discuss the general principles involved. The total span to be bridged, together with the various local circumstances, being assumed, the economical number of separate spans is first taken up and discussed in its general aspect, and afterwards theoretically, Thurin's formula being explained and applied to the present case. The number of spans having been determined upon, the type of bridge to be employed next engages attention, and the panel length having been assumed in

accordance with the best practice, an extension of "Bramwell's method" is employed to determine the economical depth and the corresponding amounts of iron in all the trusses in common use in the country. This comparison, although made for this particular case only, gives results which are believed to be approximately true for all cases, as regards the order of economy of the different trusses under like conditions. They agree admirably with the best practice, and indicate as the most economical form of truss, the Pratt, with double intersections, a truss extensively used both at home and abroad. This type being adopted, the amount and distribution of the load are next considered, and the accuracy of the usual uniform loads assumed for bridges of this span is tested by comparing the chord stresses produced by them with the actual stresses produced by a heavy train. The details of calculation of stresses and determination of dimensions are then taken up.

Two sheets of drawings accompany the thesis.

The Ashtabula Bridge. By Frank E. Wiggin.

(Abstract not received.)

DEPARTMENT OF MECHANICAL ENGINEERING.

A Review of a Continuous Brake Trial. Abstract by the author, William H. Beeching.

I have considered this subject under two parts: —

Part I gives a description of the trial-ground, the apparatus used, the trains and brakes, the experiments as they took place under the different classes, the statement of the questions to be considered, and, if possible, to be settled by this trial.

Part II deals with the calculations and questions as stated in Part I; also contains tables, with the results obtained, a number of diagrams used in the discussions. We find that the Westinghouse Automatic Brake out-did all the other brakes, in ease of application and running, promptness of action and

apparent durability. We also find that wet rails greatly decreases the coefficient of friction of the brakes, and thus their efficiency when wooden brake blocks are used, and more so than in the case of cast iron blocks.

The Westinghouse Air Brake. Abstract by the author, George W. Chapman.

The Westinghouse Air Brake is a contrivance consisting essentially of a cylinder, fitted with a piston working air-tight within. The piston rod is connected with the brake levers, and on the admission of compressed air, the piston is forced from its normal position at one end of the cylinder to the other. This movement of the piston through about ten inches, and with a pressure of ninety pounds per square inch behind it, is capable of exerting upon the wheels the same, or greater, pressure than is applied by the total weight of the cars resting upon them. The sudden resistance to the train's motion enables it to be stopped under the most adverse circumstances of speed, incline, and weather within a distance of five hundred yards, and ordinarily within five hundred feet. With the old form of hand brake, the train often runs a distance of half or three-quarters of a mile before stopping.

The air pump for compressing the air does not differ materially from the pumps used in physical experiments, but all the appendages are of necessity much stronger. The motive power is a steam engine situated directly over the pump cylinder, so that the same piston rod serves for both. The air is compressed to a pressure of from seventy to one hundred pounds per square inch, and is stored for use in a cylindrical boiler-iron reservoir, situated under the foot board on the locomotive. The details of engine, pump and brake, are numerous, but not complicated for a contrivance of such inestimable value to railroad companies for the safety of the traveling public. It seems to me that in point of simplicity and efficiency in car brakes, the acme has been attained in the Westinghouse Brake.

Double Valves as applied to the Rider Engine. Abstract by the author, Linus Faunce.

The Rider Engine is similar to most stationary engines with the exception of the valves and their connection with the governor. The main slide valve is, on its face side similar to the ordinary D valve except that it has its ends lengthened to admit of ports being formed outside of the valve proper. The ports on the face side are parallel with the ports in the cylinder and at right angles to the motion of the valve. On the back these ports are oblique and at opposite angles to each other. The expansion valve is a sector of a cylinder with its acting ends cut off obliquely in opposite directions corresponding exactly with the obliquity of the ports in the back of the main valve. It is fitted into a semicylindrical recess in the back of the main valve.

These valves are operated lengthwise by separate eccentrics, to which they are attached in the usual manner, except that the expansion valve rod has a swivel joint to permit of partial rotation, and it is so connected with the governor that when the governor rises or falls it will be made to rotate in one direction or the other.

The governor, instead of throtling the steam, regulates the point of cut off, making admission longer or shorter as there is more or less work to be done.

With proper proportioned valves and governor any degree of expansion may be obtained.

The Construction and Use of a Mercury Column. Abstract by the author, Chas. H. Fisher.

It is becoming common as more accurate results are required, for engineers to frequently test the instruments which they use in observing pressures. To do this they must, directly or indirectly, compare them with an open air mercury manometer.

In this paper, the necessary principles of the construction of

such an instrument and the interpretation of its readings, are discussed.

The ordinary pressure-indicating instruments are graduated to even pounds per square inch and may be read to the nearest tenth of a pound by estimating the tenths by the eye.

Therefore if we should, in the use of such a manometer, for the sake of convenience, introduce a small error in our interpretations, we may be certain that our result is as near as the instrument on trial can indicate, if we are sure that the error we introduce does not amount to a half of a tenth of a pound.

In using a mercury column there are two ways in which errors may be introduced. The first is in the graduation and reading of the scale with which we observe the height of the mercury. By care, this error may be kept within almost any limit we desire.

The second way an error may arise, is in the transformation of the pressure, expressed in height of mercury, to that expressed in pounds per square inch.

The pressure, in pounds per square inch, corresponding to a column of mercury h inches high, is $p = hy$, where y is the weight in pounds of a cubic inch of mercury. The value of y may vary either from a change of temperature or from the compression produced in the mercury by pressure.

In this paper are discussed the effects of these variations and the means of correcting them.

Finally, there is described a design for such a column, and a suggestion made concerning an addition, to be made to the design, for the purpose of reading the height of the mercury.

Boiler Incrustation. Abstract by the author, Joseph Kirk.

Incrustation in steam boilers is caused by impurities in the feed-water, which become concentrated in the boiler, and finally form a coating or layer on the plates or tubes. The deposit thus formed, having a low conducting power, hinders the transmission of heat from the fire to the water, involving

the expenditure of more coal than would be used if the plates and tubes are clean. The deposit also acts injuriously upon the boiler by causing the plates to be overheated, in consequence of which they may be burned, or their strength may be made insufficient to resist the pressure of the steam. If the deposit on an overheated plate is suddenly cracked off, or removed in any way, the water in the boiler is brought into contact with the plate, and the result may be a true explosion. Substances forming deposits may be divided into two classes; those dissolved by the feed-water, and those held in suspension. To the first class belong salt, lime, magnesia and iron salts; to the second, sand, mud, and vegetable matter. The method of prevention generally adopted against salt are blowing off and surface condensation. Lime is found as incrustation in two forms; carbonate and sulphate. The carbonate may be precipitated before the water enters the boiler by boiling the water, or by mixing it with lime-water. Sulphate of lime is precipitated by being boiled at a high pressure. Magnesia occurs as the carbonate and acts in a similar manner to carbonate of lime. Iron salts have a corrosive action on the boiler. They can be precipitated by boiling. Members of the second class can be removed from the feed-water by filtering. Chemical substances, especially carbonate of soda, are sometimes used in the boiler for preventing lime incrustation.

Substances having, or supposed to have, a mechanical action in preventing incrustation have been used. They often contain grease, which if present in considerable quantity is injurious to the boiler. Vessels for collecting the sediment and preventing it from being deposited on the plates or tubes are sometimes used in the boiler. When a hard coating of scale has formed it may be removed by being chipped off, or by suddenly heating or cooling the boiler. The first method is inapplicable to multitubular boilers unless the tubes are taken out. The second is liable to injure the boiler by the sudden strains introduced. The general opinion of railway men in regard to the prevention of incrustation, is that it is best to

purify the water before it goes into the boiler rather than to use chemical powders, etc., in the boiler.

On Link Motion. Abstract by the author, Cecil H. Peabody.

The idea pursued in this thesis is to take an example of link motion from actual practice, and by applying to it the different methods of working out the problem, to make a comparison of the methods and of their results, pointing out the advantages and deficiencies of each method. As an introduction, there is given a short sketch of the development of the link motion from earlier forms of reversing motions, together with a description of the form common to American practice.

The three methods applied to the problem chosen are, in order, the algebraic method, based on cinematical principles, the graphical method, and the method by use of a model with adjustable parts. The algebraic method is that given by Professor Gustav Zeuner in his treatise on Valve-gears, the problem being solved in full, both numerically and by aid of a diagram, thus obtaining an efficient check on the work. The graphical method is that given by Wm. S. Auchincloss in his Link and Valve Motions, only the simplest case being touched upon. A description of a model at the Hinkley Locomotive Works, with an account of an experiment, giving results, closes the discussion.

DEPARTMENT OF MINING ENGINEERING.

The Vershire Copper Ore and its Metallurgical Treatment.
Abstract by the author, George Bartol.

This thesis is divided into six parts.

1. Description of the ore and its constituent minerals. The composition of the ore was found to be: —

Cu	11.29 per cent.
Fe	46.76 "
S	33.98 "
SiO_2	5.67 "
Zn	1.27 "
Co and Ni undetermined.	
Pb, Al_2O_3, Ca, Mg, traces.	
	98.95 per cent.

2. A review of the advantages and disadvantages of the principal methods for the extraction of copper. Outline of the process best suited to this ore and of the one finally adopted.

3. A detailed account of the metallurgical treatment of the ore at the Institute. 1019 lbs. of the ore were treated in the following manner —

a. Roasted in a reverberatory furnace.
b. Roasted ore smelted in the blast furnace for matte.
c. Matte roasted in a kiln.
d. Roasted matte smelted in the blast furnace for black copper and matte.
e. Matte roasted in a reverberatory furnace.
f. Roasted matte smelted in crucibles for black copper and matte.

The products were: — 97½ lbs. of black copper and 2 lbs. of matte.

4. Tables giving details of furnace runs, consumption of fuel, losses of copper, etc.

5. Remarks on the size and position of tuyères, deductions from tables, suggestions and conclusions.

6. Description of the methods employed in chemical analysis.

Investigation of the Institute Ore-washers. Abstract by the author, W. C. Flint.

This report is of an examination of the work on a low grade ore from the Merrimac Mine by the ore-concentraters at the Mass. Institute of Technology, being a counterpart to the thesis of Mr. Stimpson, but not covering the same ground.

This thesis is divided into six parts.

Part I. A statement of the object of the thesis. A review of the character of the ore and the difficulties of its treament, owing to the presence of minerals of every specific gravity, from 2.5 to 7.5. A brief description of the Spitzkasten, also of the Rittinger (side-bump) and end-bump tables and dolly-tub.

Part II. Narrative of the experiments in running the machines. Tables of the records kept, also a table showing the order of operations on the ore. A statement of the final products.

Part III. A consideration of the machines from a business point of view. The proportion of metal-bearing ore saved. The cost of running the machines compared with the assay value of what was saved. The value and amount of ore saved.

Part IV. A discussion of the forces which act on bodies falling in water, also the formulæ deduced for the velocity, path, and time of fall of both spherical and irregular bodies; being the theory of grading. (Translated from Rittinger's "Lehrbuch der Aufbereitungskunde.")

Part V. Investigation of the products of boxes 2, 3, and 4 of the Spitzkasten, and of the overflow of the same, as follows:

Samples were taken and passed through sieves to size them. The sieve products were grouped into a smaller number of divisions, thus: Spitzkasten, box 2, into four: 1, through a 12th sieve on a 40th; 2, through a 40th on a 70th; 3, through a 70th on a 120th; 4, through a 120th; box 3 into three: 1, through a 12th on a 70th; 2, through a 70th on a 160th; 3, through a 160th; box 4 into three: 1, through a 12th on a

120th; 2, through a 120th on a 160th; 3, through a 160th; overflow into two; 1, through a 12th on a 160th; 2, through a 160th.

Construction of curves to show the results of this sizing. The above divisions examined for PbS, S, Fe and CO_2, and the mineral percentages calculated therefrom. Account of the analyses and results. Construction of curves to show these graphically. Tables showing the direct results of analyses, also the mineral percentages.

TABLE OF DIRECT RESULTS.

		Per cent. PbS.	Per cent. S	Per cent. CO_2.	Per cent. Fe.
Box 2 of Spitzkasten.	Division 1.	1.96	1.83	6.17 5.96	7.17
	" 2.	2.10	2.33	6.89 6.72	8.25
	" 3.	5.28	5.05	9.73 9.42	12.42
	" 4.	15.42	8.08	9.23 9.31	18.11
Box 3 of Spitzkasten.	" 1.	2.61	1.82	4.85	6.53
	" 2.	4.56	2.68	7.89	8.99
	" 3.	8.63	6.92	9.48	13.32
Box 4 of Spitzkasten.	" 1.	1.69	1.30	4.15	4.64 4.75
	" 2.	2.87	1.97	7.40	8.36
	" 3.	9.90	5.84	9.78	12.65
Overflow of Spitzkasten.	" 1.	4.70	3.895 3.95	6.60	7.62
	" 2.	9.65	3.52 3.49	8.82	9.76

TABLE OF MINERAL PERCENTAGES.

		Per cent. Galena.	Per cent. Pyrite.	Per cent. Siderite.	Per cent. Gangue.	Total per ct.
Box 2 of Spitzkasten.	Division 1.	1.96	2.94	16.27	78.43	99.60
	" 2.	2.10	3.84	17.92	71.70	95.56
	" 3.	5.28	8.14	25.23	59.48	98.13
	" 4.	15.42	11.27	24.44	48.80	99.93
Box 3 of Spitzkasten.	" 1.	2.61	2.76	12.78	77.15	95.30
	" 2.	4.56	3.88	20.80	69.88	99.12
	" 3.	8.63	10.80	24.99	49.39	93.81
Box 4 of Spitzkasten.	" 1.	1.69	2.01	10.94	83.35	97.99
	" 2.	2.87	2.98	19.51	71.69	97.05
	" 3.	9.90	8.46	25.78	53.18	97.32
Overflow of Spitzkasten.	" 1.	4.70	6.17	17.40	70.34	98.61
	" 7.	9.65	4.14	23.26	61.94	98.99
Calculated from the above table and the weights of each product.	Total Box 2.	5.93	6.69	21.45	63.73	97.80
	" " 3.	6.38	7.53	22.55	60.66	97.12
	" " 4.	8.05	7.02	24.02	58.47	97.56
	Total Overflow.	9.32	4.28	22.86	62.49	98.95

The residue insoluble in HNO_3 and $KClO_3$ was weighed and called the amount of gangue.

Part VI. Conclusions drawn from the results obtained in Part V, considered together with the theory given in Part IV. Suggestions as to the reasons why the spitzkasten did not do better grading. Changes advisable in the spitzkasten. Changes which would be made in the investigation if repeated.

On some Methods for the Extraction of Nickel and Cobalt from their Ores. Abstract by the author, John E. Hardman.

This paper is divided into five parts.

1. The object of the thesis, showing the increasing importance of nickel and cobalt ores, the scanty knowledge we have of the metallurgy of these elements, and giving a plan of the thesis.

2. A statement, or description, of methods actually in use for the extraction of these metals, so far as the methods are known, on account of the secrecy with which the processes are kept by the proprietors. The details of two methods, one in use at Klefoa in Sweden, and the other at Dillenburg in Germany, are given.

3. A narration of experiments undertaken in accordance with the object of the thesis. Six series of experiments are described in full, and the results tabulated.

4. General deductions from, and applications of the results given in 3.

5. A detailed account of results obtained from an investigation of (1) Fischer's, (2) Rose's, and (3) Fleischer's methods for the quantitative separation and determination of cobalt and nickel, together with some facts regarding the chemistry of the two elements which are not generally noted in text-books; and some analyses of ores used during the whole investigation.

On the Smelting of a Silver-lead Ore from Merrimac Mine. Abstract by the author, Henry D. Hibbard.

A lot of low grade ore weighing 4¼ tons, from the Merrimac Mine of Newburyport, was washed by the machines at the In-

stitute, and, by this treatment a No. 1 Smelting ore containing lead and silver, and a No. 2 second grade ore which held a good deal of silver but very little lead, were obtained. This lot of No. 2 was worked by Messrs. Jenney and Wood. The subsequent working of the No. 1 lot forms the subject of this thesis.

The ore weighed 628 lbs. containing 254 lbs. of lead and 6.15 oz. of silver. Its composition is here given.

Silica	Si_2O	6.2
Iron	Fe	14.6
Alumina	Al_2O_3	.7
Lead	Pb	40.4
Silver	Ag	.067
Copper	Cu	.6
Zinc	Zn	.7
Magnesia	MgO	3.3
Sulphur	S	18.19

This ore was first roasted in lots of 46 lbs. each for four hours on a furnace with hearth $3' \times 3\frac{1}{2}'$. The loss of lead in fume was $20\frac{1}{2}$ lbs. or 8.07 per cent. of all the lead in the ore; the per cent. of sulphur was diminished from 18.9 per cent. to 3.28 per cent.

The ore was next agglomerated to get it into better condition to go into the blast furnace, this operation converts the fine ore into lumps and thereby lessens the loss of ore in dust when it is worked in the blast furnace. The loss of lead in fume during the agglomerating was 11 lbs., or 4.3 per cent. of all the lead.

The ore was next smelted in the blast furnace to make argentiferous pig lead. The mixture of ore and fluxes used in running the furnace was

Ore	40 lbs.
Tapcinder	13
Limestone	3
Siliceous Slimes	$1\frac{1}{2}$
	$57\frac{1}{2}$

This mixture was fed with one seventh its weight of coke during the whole run. The composition of the fluxes was

		Tapcinder.	Limestone.	Slimes.
Silica	SiO_2	14.55	.5	45.79
Iron oxide	FeO	70.89	.0	21.
Alumina	Al_2O_3	8.08	.0	8.95
Lime	CaO	2.38	56.	4.01
Lead	Pb	.0	.0	7.61
Magnesia	MgO	.0	.0	7.72

This smelt gave a slag of the following composition:

Silica	SiO_2	24.28
Iron oxide	FeO	52.20
Alumina	Al_2O_3	10.48
Lime	CaO	5.30
Lead	Pb	4.44
Magnesia	MgO	1.37

During this smelting 81⅞ lbs. of lead or 32.23 per cent. of all the lead was lost partly in fume, partly in drops in the slag and partly as silicate in the slag, the proportional amounts however, of these several losses were not obtained.

This lead was then melted and desilverized by pouring into it 1 per cent. of melted zinc which rises to the top and carries with it the silver and gold. This addition of zinc and the separation of argentiferous zinc scum has to be repeated several times as follows:

Before 1st addition of zinc the lead contained 64 oz. silver per ton 2000 lbs.
After " " " " rem'n'ng " 16 " " "
" 2d " " " " " 2.48 " "
" 3d " " " " " .22 " "

The zinc was now distilled off from this alloy of lead. Zinc and silver and an alloy of lead and silver were left which were separated on a cupel. The loss of lead during the desilverizing was 1⅞ lbs. or 73 per cent. of the whole lead in the ore and in cupelling 3½ lbs. of lead or 1.34 per cent. were lost.

To sum up the losses were as follows:

Lead lost in roasting . . .	20½ lbs., or	8.07	per cent.
" " " agglomerating .	11 "	4.30	"
" " " smelting .	81⅞ "	32.23	"
" " " zincing . .	1⅞ "	.73	"
" " " cupelling, etc. .	3½ "	1.37	"
Total . . .	118¾ lbs., or	46.70	per cent.

Total amount of lead obtained was 135¼ lbs. or 53.30 per cent.
The record of the silver is as follows:

The ore contained 6.15 oz.			
In roasting and smelting the loss was	1.38 oz., or	22.44	per cent.
" refining and zincing "	1.09 "	16.09	"
" cupelling "	.21 "	3.41	"
Total lost . .	2.68 oz., or	41.94	per cent.
Total amount of silver obtained .	3.47 "	58.06	"

The record of the gold:

The ore contained $4.50.			
Lost in roasting and smelting . .	$ .42 or	9.33	per cent.
" refining, zincing, and cupelling	$1.28	28.4	"
Total lost . . .	$1.70	37.73	"
Total obtained . . .	$2.80	62.27	"

Report on the Working, for Silver and Gold, of a Middle Grade Product from Ore of the Merrimac Mine, Newburyport. Abstract by the author, Walter Jenney.

The object was, to so concentrate the ore as to make a second or middle grade product which should contain minerals whose specific gravity would not allow them to be saved in the "Smelting Ore" without greatly diluting it, but which were supposed to carry quite a quantity of silver. Several processes were to be tried with the intention of finding, if possible, a method by which it would be possible to work such a product profitably.

8500 lbs. of ore from the mine, when so concentrated, gave 1272 lbs. of this middle product, which assayed for gold $9.23

per ton, and for silver $11.28 per ton. The finding of so much gold was something of a surprise and caused the methods to be altered somewhat so to extract that also. The product was made up of quartz 20.654 per cent., siderite 37.204 per cent., pyrite 20.377 per cent., galena 11.589 per cent., and smaller quantities of ispickel, chalcopyrite, blende and serpentine. It was roasted in a reverberatory furnace till all odor of SO_2 had ceased coming off, and then ground with salt (5 per cent.) and roasted again. Assays showed that in this first roasting, 38 per cent. of the gold, and 23 per cent. of the silver were lost. Experiments were made by (I) Amalgamating this chlorinated ore in a Washoe Pan — and by (II) chlorinating it with Cl gas, dissolving in brine, precipitating as sulphides, running down with lead and cupelling, with the results shown below.

Amalgamating.	Per cent. extracted form *roasted* ore	.	.	Au 17,	Ag 23.
Gas Chlorination	I.	"	"	"	"	.	.	" 41,	" 70
"	II.	"	"	"	"	.	.	" 82,	" 61.

It will be seen that the chlorination process (with Cl. gas) worked much the best, and it would give much better results if the leaching had been carried on farther.

Assays of the different products are given below: —

	Silver.	Gold.
Raw ore assayed	$11.28	$9.23
Roasted ore (before chlorination) . .	11.91	——
Chlorinated ore	11.06	7.23
Tailings from Amalgamation . . .	6.80	6.03
" " Gas chlo. I. . . .	1.70	4.82
" " " " II. . . .	1.70	3.61

The inference is that on a similar product which would be obtained from a richer ore (this being a *very* poor ore) this process might be made to pay, especially if made to work continuously as could easily be done.

Treatment of Vershire, Vt., Copper Ore. Abstract by the author, H. C. Southworth.

The thesis was divided according to the following outline:

1. The ore, with its ultimate analysis and minerals contained.

2. An account of the treatment of the ore, and a description of the processes used.

3. Deductions from my experience in working the ore, with the modifications of treatment suggested by that experience, and the comparison of the methods, with remarks upon them.

4. Tables relating to blast furnace runs, roasts, analyses, etc.

The result of the work upon the ore, as is stated in Part 2 of the thesis, was a black copper containing about 98 per cent. of copper.

This was accomplished by two roasts in the kiln, and smelting twice in the blast furnace, and then taking the second matte and running it down in black lead crucibles, after roasting as well as possible in the reverbertory furnace.

The most interesting comparison is that of the work of the kiln with the reverbertory furnace, upon the same ore. This is shown by the following table:

	Roasting in Kiln.	Reverberatory.	
Amount of ore roasted	865⅜	1019¼	lbs.
" " fuel used	105⅛ (coke)	739 (coal)	lbs.
" " labor	8	52	hrs.
" " sulphur lost	131	122	lbs.
Percentage " "	15.14	about 12.	

As the reverbertory furnace was used by Mr. Bartol, I am indebted to him for a part of the information concerning the above table.

In speaking of modifications of treatment, the view was expressed that, by sufficient roasting — which could be done in the kiln — the ore might be run down at once into as good a matte as was got by smelting twice.

In this way a good black copper would be got with only two furnace runs.

Investigation into the Working of the Institute Ore-concentrating Machines. Abstract by the author, Thomas F. Stimpson.

This subject was divided for study between Mr. Wm. C. Flint and myself. The ore to be experimented upon was a very poor quality argentiferous galena ore from the Merrimac Mine, Newbury, and was found by inspection to consist of the following minerals: — Galena, Chalcopyrite, Quartz, Pyrite, Siderite, Arsenopyrite, Zinc-blende, Tetrahedrite and traprock, associated with the greenish-white gangue composed essentially of Silicate of Alumina. It was broken, crushed, and sifted, by the machine in the Mining Laboratory of the Institute. Of the 8485 lbs. ready for concentration a sample was taken and subjected to chemical analysis, with the following results: —

Lead	5.23 per cent.
Sulphur	5.45 "
Iron	4.24 "
Ferrous Oxide	9.24 "
Copper	.32 "
Arsenic	.27 "
Alumina	8.30 "
Oxide of Manganese	1.01 "
Zinc	.15 "
Lime	1.16 "
Magnesia	1.39 "
Alkalies	1.95 "
Carbonic Acid	7.02 "
Silicic Acid	52.75 "
Water	.96 "
Determined	99.44 per cent.

From the above the mineral constituents were calculated as follows: —

Galena	6.04 per cent.
Siderite containing manganese	18.51 "
Pyrite	7.36 "
Chalcopyrite	.93 "
Arsenopyrite	.90 "
Zinc-blende	.46 "
Siliceous gangue	65.24 "
Total	99.44 per cent.

An assay for the precious metals gave: —

Silver	.020	per cent.; 5.83 oz. to the ton.
Gold	.00067	per cent.; 196 oz. to the ton.

The subject was treated more or less fully under six headings, viz: —

1. Description of the Ore and Machines.
2. Narration of Experiments. Final Products made.
3. Estimation of the Cost of Running the Machines. Value of the Final Products made.
4. Theory of Concentration.
5. Investigation of Results. Comparison with the Theory (not fully completed).
6. Conclusions.

1. The description of the machines was confined to the Cone, the Spitzkasten and the Jigger.

2. The time occupied in concentrating the ore was about 29¼ hours, extending over a period of five days. The object in view, meanwhile, was to make two workable products of ore: (1) One which was rich in lead — a smelting ore; (2) a product which should be poor in lead but carrying silver which was to be extracted either by chlorination or by amalgamation.

The following are the workable products made during the run.

	Weight lbs.	*Per cent. Lead.*	*Per cent. Silver.*
Smelting Ore	624¼	38.03	.049
Middle Grade Ore . . .	1823½	8.97	.031

3. The object of considering the cost of running the mill in the Laboratory was more especially to gain some idea of the cost of working similar ores on a larger and more practical scale. It is evident that, by increasing the capacity of the machine, the cost of concentrating an ore could be greatly diminished.

The principal data for this purpose are presented as follows:—

	Weight. lbs.	*Value Lead.*	*Value Silver.*
The Ore before treatment . .	8485	$26.63	$27.24
Smelting Ore produced . .	624¼	$14.24	$4.86
Middle Grade Ore produced .	1823½	9.81	9.23
Waste	6037¼	4.47	11.38
	8485	$28.52	$25.47
Unaccounted for: Lead, 32 lbs. at 6 cts.		— 1.89	
Silver, 1.61 oz. at $1.10			1.77
		$26.63	$27.24

Cost of working ore:

Interest on capital of $1800, including wear, per day	$ .50	
Wages of 2 men at $2.00	4.00	
" " 2 boys at .75	1.50	
Coal for generating steam	.75	
Oil for lubricating	.25	
Cost per day . . .	$7.00	
Total cost for five days .		$35.00

4. In ore-working there are usually two distinct processes: 1. *Sorting*, by which the ore is separated into groups whose particles have a like falling-velocity in water; 2. *Sizing*, by which the coarser grains are separated from the finer, and by which, if the ore had previously been sorted, a concentration takes place.

5. In investigating the results of the experiment the investigation extended to the work done by the Cone, Spitzkasten No. 1, and the Jigger, in order to inquire into the proficiency of these machines as "sorters" or "sizers" — as the case happened to be. The results depended upon the chemical analysis, and the physical examination of the different sizes of grains in each product to be investigated.

6. An examination of some of the products showed that the concentration of the ore, in respect to its silver, was rendered particularly difficult on account of the manner in which that metal was disseminated throughout the whole mass

of ore; and, on the other hand, the concentrations for lead would have been much richer but for the manner in which particles of quartz and siderite were disseminated through the galena giving to it thereby a lower specific gravity. It is thought that a further study of the data already obtained will show that the machines did their work as completely as possible, considering the peculiar physical condition of the ore and the manner in which the process of concentration was necessarily hastened.

Experimental Working, by Wet and Dry Methods, of a Low Grade Silver and Gold Ore, from Newbury, Mass. Abstract by the author, F. W. Wood.

Three principal divisions may be made of this thesis as follows:

1. Description of certain wet and dry processes for the extraction of silver.
2. Description of the ore experimented upon.
3. Description of the experiments conducted in the Metallurgical laboratory, with conclusions drawn from the results.

In Part 1st it is endeavored to give, in as compact form as possible, descriptions of the following named processes with the chemical reactions involved in each: — Washoe amalgamation, Augustin, Ziervogel, Von Patera, and a smelting process used at Freiberg.

It was originally intended to conduct the experiments upon an argentiferous zinc blende, but as this could not be obtained, a middle grade product, separated in the washing of $8\frac{1}{3}$ tons of low grade ore from the Merrimac mine at Newbury, was substituted.

Part 2d gives a scheme of the washing, showing the products making up the ore experimented upon, an analysis of the ore, with some of the methods of determination employed, a calculation of the mineral species, and the results of assays of the ore.

Part 3d is devoted entirely to the description of the experiments which were as follows: —

1. Trial roast and lixiviation to determine the possibility of extracting any of the silver in the above ore by a wet method.

2. The working of 100 lbs. of ore by Augustin's process.

3. Experiment upon 500 grms. to determine the possibility of applying Ziervogel's process.

4. The working of 100 lbs. of ore by Von Patera's process.

5. The smelting of 100 lbs. for matte and the subsequent treatment of one fourth of the matte, for silver and gold, in the dry way.

The following are the results of the different processes: —

	Obtained, per cent.		*Lost, per cent.*	
	Silver.	Gold.	Silver.	Gold.
Trial Roast .	. 7.8		92.2	
Augustin's .	. 23.7	14.3	76.3	85.8
Von Patera's .	. 24.7	18.6	75.3	81.4
Smelting .	. 33.3	62.9	66.7	37.1

The *per centage lost* includes the silver and gold in the residues from the wet processes.

The loss in Augustin's process was increased by the breaking of a crucible while in the furnace.

In the dry process, the roasting of the matte obtained by the first smelting was carried so far that not enough sulphur for the formation of a matte in the second smelting remained, hence a considerable portion of lead, and with it the silver, went into the slag.

The conclusion drawn from the experiments is, that in order to economically extract the gold and silver, instead of attempting to work such a product alone, it should be smelted with an ore rich in lead.

Design for a Steam Fire Engine House. Abstract by the author, J. William Beal.

It was the object in this thesis to present the subject, not merely from an architectural point of view with regard to design and execution of drawing alone (although these were given the most careful attention), but more particularly from a practical point of view adapting the *theoretical* to the practical requirements of the problem, according to one's best judgment. This course, although it may not present such pleasing results as may have been obtained by selecting some subject involving more architectural design, has nevertheless served to initiate the student into the routine of service in actual work which is of the greatest value. To accomplish this object, thorough examinations were made into the Fire Department of Boston and Cambridge; through the kindness of the officers the practical workings of each branch of the department were shown. The Engine Houses varying from one another, the advantages or disadvantages of each were ascertained. In accordance with the information thus obtained the design was worked out, all points of construction being treated exactly as though it was an actual case of building, in every case the theoretical calculations being compared with work already executed. These calculations embraced calculation of girders and timbers for floors, calculation of foundations and retaining walls, the distribution of strains in the roof trusses and the calculation of their dimensions, also the stability of arches and their effect on walls. The drawings comprised directions, plans and sections, with details and a perspective view of the building.

A Town Hall. Abstract by the author, Geo. W. Capen.

The subject of this thesis, "A Town Hall" was chosen for a variety of reasons, the principal of which were, that there is comparatively little architecture in our country towns, also that

it afforded a good field for architectural composition and design, and lastly a good opportunity for the calculation of strength and stability.

The building was to be built of rough stone and was designed to meet the wants of a town of from five to six thousand inhabitants. It contained on the lower floor, offices for the town clerk (which office was provided with a fire-proof vault), tax collector, selectmen and janitor, besides a large library room and a hall for small public gatherings.

The whole of the second floor was occupied by a large and spacious hall for large public gatherings, which was provided with two suits of dressing rooms, one for ladies and one for gentlemen.

The hall was to be covered by an open timbered roof, with a balcony in the rear, a large and commodious stage in front and a long narrow balcony on either side supported by brackets which form an architectural composition with the roof trusses.

The design is executed in the modern gothic style, and has for its principal exterior feature, a clock tower with a dial facing each of the cardinal points of the compass.

Of the drawings accompanying the thesis, there were a front elevation, a ground plan and a hall plan drawn to a quarter-inch scale — a side elevation, a longitudinal and transverse section and a gallery plan drawn to an eighth-inch scale, besides a perspective drawn to a quarter-inch scale.

A Design for a Steam Fire-Engine House. Abstract by the author, W. E. Chamberlin.

The conditions of the problem were assumed as follows: —

A flourishing suburban town requires a house for a steam fire-engine with its hose-carriage, and accommodations for six "permanent men." The house, which is to be of brick and stone, is to have a tower where the hose is hung to dry.

The principal story is for the most part taken up by the large room where the apparatus stands. In the rear the stalls are arranged, also an office and a workshop.

The second story contains six sleeping rooms as near as possible to the staircase which is in a single run. There is also a parlor, a room for the fire-alarm battery, a bath-room and a grain room.

In the cellar are found the hose-trough, the heating-apparatus, &c., &c.

The tower, which is usually put on the rear of the building, has in this case been put on the front. This position, while detracting nothing from the convenience within, gives an opportunity for making the building more pleasing without.

In order to be assured of the best arrangements for the planning of the problem several of the best houses in Boston and Cambridge were visited, and useful hints obtained.

The drawings accompanying the text consisted of plans of the first and second stories and cellar, the two principal elevations, a longitudinal section, a perspective and a few details on a larger scale.

For mathematical calculations the following were made:

1. Dimensions of floor timbers in engine-room, (assuming the weight of engine ready for a fire as 8000 lbs. The fact that two-thirds of this comes upon the hind wheels was considered.)
2. Truss 32 ft. long in partition in 2d story.
3. Parlor flooring timbers.
4. Roof truss (this was a primary truss of 32 ft. span, each slope being braced by a strut from the bottom of the vertical tie-rod.)
5. The brick arches on the front of the house.

Design for a Railroad Station. Abstract by the author, Pierce P. Furber.

In the design accommodation was afforded for waiting rooms for both ladies and gentlemen, baggage and lunch rooms, freight, telegraph and ticket offices, with the necessary halls, vestibules, and side rooms, in a two story building, 32 ×

44 feet, having a one story wing, 32 × 53 feet, the material used being red brick with brown stone trimmings and blue slate roofs.

The accompanying drawings consisted of two floor plans, a piling plan, two elevations, a section, and perspective, all drawn to a scale of one-eighth of an inch to a foot. Calculations were made as to the number of piles necessary to support the building in a loose sandy soil, and as to the stability of the arch over the main entrance.

A design was made for the roof trusses, the proper dimensions of the different members composing them being determined by the aid of "Greene's Graphical Analysis of Roof Trusses," a load of 12 pounds per square foot of snow, and a wind pressure of 26.5 pounds per square foot being taken into consideration. The strength of the floors was discussed, as was the construction of a trussed partition.

DEPARTMENT OF CHEMISTRY.

On an impurity found in Commercial Acetone. Abstract by the author, John Alden.

In repeating Baeyer's experiments on the formation of Phorone by passing dry chlorhydric acid gas into Acetone, a solid crystalline body was formed, a fact not mentioned by Baeyer, or by those who have since repeated his experiment. The purification and analysis of this body form the subject of the thesis.

From the analysis made the body was judged to have the formulæ $C_4H_{11}N_2O_2Cl$ as the following results show: —

Carbon	31.45	31.07
Hydrogen	7.80	7.12
Nitrogen	17.45	18.12
Chlorine	23.10	22.98
Oxygen	20.55	20.71
	100.00	100.00

Judging from the reactions the body evidently had an acid structure, and a double arindo-structure. As the body was first formed, both groups of NH_2 were evidently saturated with HCl, but on exposure to the air HCl was given off, till finally only one remained combined.

The formation of this nitrogenous body was evidently due to an impurity in the acetone. Certain tests and analyses led to the conclusion that it was acetonitrile. To verify this conclusion, some pure acetone and acetonitrile were made, and the mixture of the two saturated with HCl, when the same crystalline body was formed, having the same properties and constitution.

The acetone was probably prepared from the by-products of aniline manufacture by Béchamp's process, in which it occurs. This would account for the presence of acetonitrile.

The relations of Carbon to Iron and its determination by the Chlorine Process. Abstract by the author, Chas. S. Bachelder.

The subject is treated as follows:—

I. Relations of Carbon, Silicon and Manganese to Iron: — In this section is considered the importance of knowledge of the above named ingredients of commercial iron, as seriously affecting its value for different purposes; also the form in which these elements are supposed to exist in the Iron.

II. Methods of determining total carbon and the Möhler Chlorine Process:— Under this head is discussed the various methods for determining carbon, more especially that known as the Chlorine Process.

III. Experiments with the Chlorine Process: — In this section the results of a number of analyses are given, the various defects in the process pointed out, and methods given for avoiding them as far as possible. The conclusion is reached that when properly carried out the Chlorine process affords results, which compare not only with themselves, but also with those given by what are considered to be accurate methods.

LOWELL DEPARTMENT OF INDUSTRIAL DESIGN FOR 1876–77.

President Runkle: —

Dear Sir: — At the close of my fifth year I have the honor of submitting to you the following report. Of the graduates, twenty-two are in situations, besides a number of others who have left the school before the completion of the course, to finish their apprenticeship in mills as they have received offers of places. In my last report, it was stated that designers for silk and woolen goods must understand weaving, and the art of putting a design on the loom, During the past year we have established such a course; and the looms now in possession of the department have been presented, one by the Lewiston Machine Co. of Lewiston, Me; one by the Bridesburg Manufacturing Co. of Philadelphia; one, an English loom, by Mr. Edward A. Brigham of Boston; and two by Mr. George Crompton of Worcester, one a twenty-harness and four-shuttle loom, and one an improved Jacquard pattern-loom, expressly designed and built for the department. Messrs. Mudge, Sawyer & Co. have also kindly furnished us with the needed cotton and woolen yarns.

The object of this department is not simply to teach weaving, but to give the student a general idea of the way in which all woven fabrics are made, and to teach him to dissect any sample of cloth, and to reproduce it upon the loom, as well as to exhibit his own designs in the woven fabric. The following is a general outline of the course, which is in the immediate charge of Mr. A. D. Blodgett.

The first five lessons are devoted to learning the names of the various parts of the loom, and the function of each, the

drawing in, and mending of, the warp-threads, the filling of the shuttle, the oiling, the starting and the stopping of the loom, and the weaving of a simple cloth with two or three harnesses and one shuttle.

The sixth lesson is devoted to putting the warp into the loom, hanging the harnesses, and setting the reed.

The seventh lesson teaches the running of a loom with eight to twelve harnesses and one or two shuttles.

The five following lessons are devoted to designing and weaving patterns upon an eight-harness loom running four shuttles.

The eight following exercises are upon designing, setting up, and weaving patterns upon a twenty-harness loom and four shuttles.

Two lessons upon drawing in warps from drawing drafts made by the student. The work done in these two lessons is put upon the loom and woven.

The next eight lessons are upon an improved Crompton-Jacquard loom, consisting of designing, setting up, drawing in, and weaving various patterns.

The following is a list of the pupils who are now in situations: —

James L. Folsom	Hartford Carpet Co.	
Alex. Johnson	Pacific Mills	Boston.
Carroll S. Faunce	" "	New York.
Sam'l Hudson	" "	Lawrence.
Everett Anthes	Manchester Print Co.	Boston.
Mary Jefferson	" "	"
Elizabeth Mendum	" "	"
Chas. H. Cowdrey	Oriental Print Co.	"
Wm. Schroeder	" "	"
Edwin Foster	" "	"
Addie S. Bartlett	" "	"
Caroline Egerton	" "	"
Caroline A. Stafford	" "	"
Minnie E. Ricker	Hamilton Print Co.	"
Harriet A. Parker	Roxbury Carpet Co.	

Howard G. Hinckley	Merrimac Print Co.	Boston.
S. R. Eaton	" "	"
Edgar Eames	" "	"
Chas. H. Underwood	" "	"
Henry Symmes	" "	"
Reuben Winslow	" "	"
Frank Hyde	" "	"
Chas. A. Washburn	Sanford's Carpet Mills	New York.
Eva M. Close	Forbes' Lithograph Co.	Boston.
Henry P. Mabille	American Print Co.	New York.
Annie D. Stimers	Sprague Print Co.	"
John H. Tarbell	Donnell Manufac. Co.	
Edward Williams	Lithographer	Boston.
Henry Morse	Carpet Mills	Maine.

Respectfully submitted,

CHARLES KASTNER, *Director.*

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OF THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,

MARCH 1, 1878.

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* Prof. Daniel Treadwell, Cambridge, Mass.

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Allen, Stephen M. . Boston.
Amory, William . . "
Atkinson, Edward . "

Baker, William E. . "
*Bancroft, E. P. . "
*Beebe, James M. . "
Bowditch, J. I. . . "
Bowditch, Mrs. J. I. "
Brimmer, Martin . "
Browne, C. Allen . "
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Colby, Gardner . . "
Cummings, John . . Woburn.

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Davenport, Henry . "
Dupee, James A. . "

*Edmands, J. Wiley. "
*Eldredge, E. H. . "
Emerson, George B. "
Endicott, Wm., Jr. . "

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Fay, Mrs. Sarah S. . "
Forbes, John M. . . "
Forbes, Robert B. . "
Foster, John . . . "

Gaffield, Thomas . . "
*Gardner, G. A. . . "
Gardner, John L. . "
Gookin, Samuel H. . "
*Grant, Michael . . "
Greenleaf, R. C. . . "
Grover, Wm. O. . . "

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Hoadley, J. C. . . Lawrence.
*Huntington, Ralph . Boston.

Johnson, Samuel. . "

Kidder, Henry P. . "
Kuhn, Geo. H. . . "

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Lee, Henry . . . "
*Lee, John C. . . . "
* Lee, Thomas . . "
Lee, Thomas J. "
Little, James L. . . "
Lowell, John A. . . "
Lyman, Geo. W. . "

Matthews, Nathan . "
*McGregor, James . "
Mudge, E. R. . . . "

Nichols, Lyman . . "
Norcross, Otis . . "

*Pierce, Carlos . . Canada.
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Pratt, Mrs. William . "
Pratt Miss . . . . "

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*Richardson, J. B. . "
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Rogers, William B. . "
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Ross, Waldo O. . . "
Ruggles, S. P. . . Boston.

* Deceased.

*Savage, James	Boston.
Sayles Henry	"
Sayles, Mrs. Willard	"
*Sears David	"
Shaw, Mary S.	"
*Skinner, Francis	"
*Stetson, Joshua	"
Thayer, Nathaniel	"
Thorndike, John H.	"
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*Turner, J. M.	"
*Upton, George B.	"
Wales, Geo. W.	"
Wales, T. B.	"
Wales, Miss	"
*Whitney, Joseph	"
Wolcott, J. H.	"

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Adams, James	Charlestown.
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Appleton, Thos. G.	Boston.
Atkinson, Wm. P.	"
Austin, Edward	"
Batchelder, John M.	Cambridge.
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Bender, Richard W.	"
Bigelow, A. O.	"
Bigelow, Jacob	"
Bishop, Chas. J.	"
Bond, George W.	W. Roxbury.
Bond, W. S.	"
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Bowditch, Wm. I.	Brookline.
Browne, Causten	Boston.
Cabot, Samuel	"
Carpenter, Geo. O.	"
Carruth, Charles	"
Clapp, Wm. W.	"
Clinch, John M.	"
Cummings, Nath'l	"
Curtis, Frederick	"
Davis, Barnabas	"
Delano, Jos. C	New Bedford.
Denny, Henry G.	Boston.
Dewson, F. A.	"
Dix, John H.	Boston.
Dresser, Jacob A.	"
Eastman, Ambrose	"
Farmer, Moses G.	"
Flint, Charles L.	"
Foss, L. Bacon	"
Francis, James B.	Lowell.
Fuller, H. Weld	Boston.
Gardner, James B.	"
Gibbens, Joseph M.	"
Grandgent, L. H.	"
Guild, Chester	"
Guild, Henry	"
Hall, Thomas	"
Hammond, George W.	"
Haven, Franklin.	"
Hayes, S. Dana	"
Heard, John T.	"
Henck, John B.	Brookline.
Henshaw, John A.	Cambridge.
Hewins, Edmund H.	Boston.
Holmes, O. W.	"
Homans, C. D.	"
Hubbard, Charles T.	"
Hyde, George B.	"
Hyde, Henry D.	"
Jackson, J. B. S.	"
Jasper, Gustavus A.	"
Jenks, Lewis E.	"
Kehew, John	"
Kneeland, Samuel	"

Lamson, Chas. D. . Boston.
Langley, H. P. . . "
Lanza, Gaetano . . "
Lawrence, A. A. . "
Lee, Francis L. . . "
Leuchars, R. B. . . "
Lewis, Charles W. . Charlestown.
Lewis, Wm. K. . . Boston.
Lincoln, F. W. . . "
Little, James L., Jr. "
Little, John M. . . "
Lothrop, Sam'l K. . "
Lowe, N. M. . . . "
Lowell, John . . . "
Lyman, Theodore . Brookline.

Mansfield, A. K. . Cambridge.
Markoe, G. F. H. . Boston.
Mason, Robert M. . "
May, F. W. G. . . Dorchester.
May, John J. . . . "
McMurtrie, Horace . Boston.
McPherson, W. J. . "
Merrill, N. F. . . . Cambridgep't.
Montgomery, Hugh . Boston.
Moore, Alex. . . . "

Newell, John . . . "
Nichols, James R. . Haverhill.
Norton, Jacob . . Boston.

Ordway, John M. . W. Roxbury.

Page, W. H. . . . Boston.
Parsons, Wm. . . "
Paul, J. F. . . . . "
Peabody, O. W. . . "
Perry, O. H. . . . "
Philbrick, Edward S. "
Philbrick, John D. . "
Pickering, E. C. . . "
Pickering, H. W. . "
Pope, Edward E. . "
Prang, Louis . . . "
Putnam, J. P. . . . "

Rice, Alexander H. . Boston.
Richards, R. H. . . "

Ritchie, E. S. . . . Brookline.
Robbins, James M. . Milton.
Robinson, J. R. . . Boston.
Rotch, Benj. S. . . "
Ruggles, John . . "
Runkle, John D. . Brookline.
Russell, LeBaron . Boston.

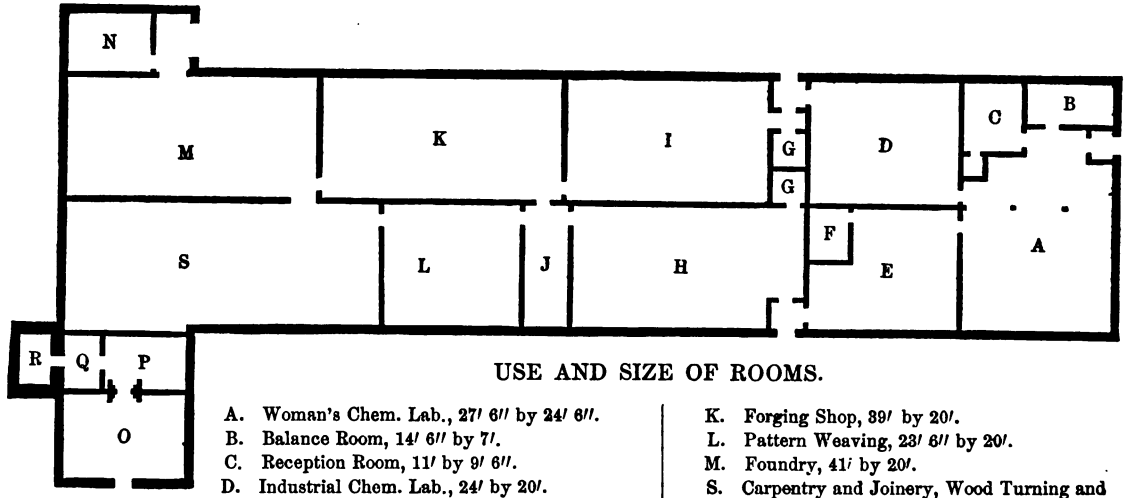
Salisbury, D. Waldo "
Sawyer, Edward . Newton.
Sawyer, Timothy T. Charlestown.
Sears, Philip H. . . Boston.
Sherwin, Thos. . . Dedham.
Shimmin, Chas. F. . Boston.
Shurtleff, A. M. . . "
Sinclair, Alex. D. . "
Smith, Chauncy . . Cambridge.
Sprague, Chas. J. . Boston.
Stevens, Benj. F. . "
Sturgis, John H. . "
Sullivan, Richard . "

Thompson, Wm. H. "
Tufts, John W. . . "

Upham, J. B. . . "
Urbino, S. R. . . . "

Ware, Chas. E. . . "
Ware, Wm. R. . . "
Warren, Cyrus M. . Brookline.
Warren, Geo. W. . Boston.
Warren, Joseph H. . "
Warren, Sam'l D. . "
Waters, C. H. . . . Clinton.
Watson, R. S. . . Milton.
Watson, Wm. . . Boston.
Weston, David M. . "
Whitaker, Channing "
Whitman, Herbert T. "
Whitmore, Wm. H. . "
Whiton, David . . "
Wilder, Marshall P. Dorchester.
Williams, H. W. . . Boston.
Winthrop, Robert C. "
Wright, John H. . . "
Wyman, Morrill . . Cambridge.

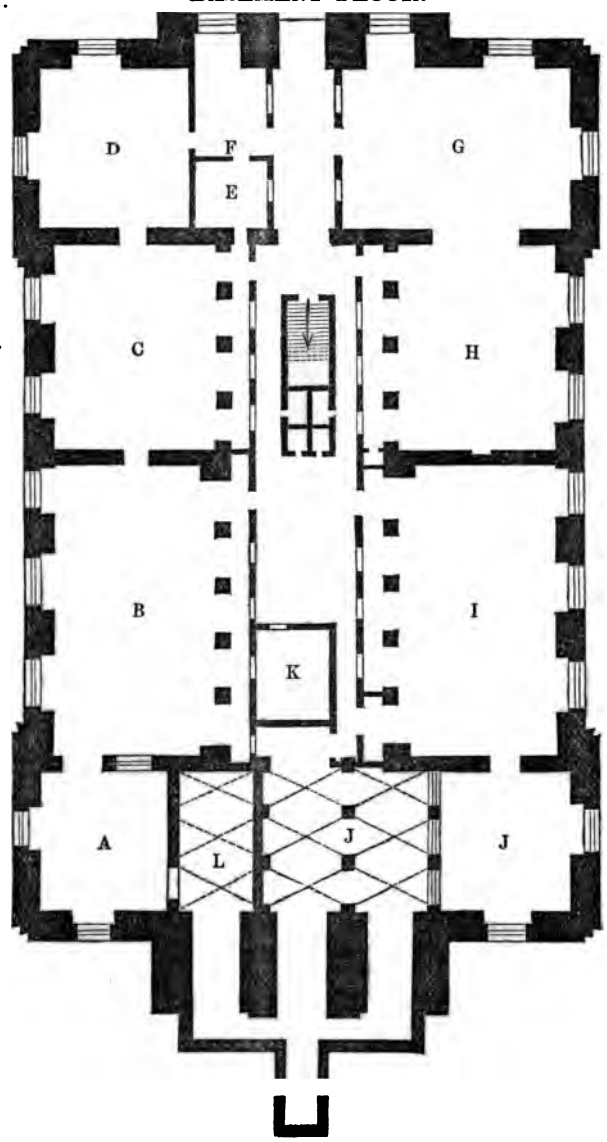
NEW TEMPORARY BUILDING FOR SHOP-WORK AND CHEMISTRY.



USE AND SIZE OF ROOMS.

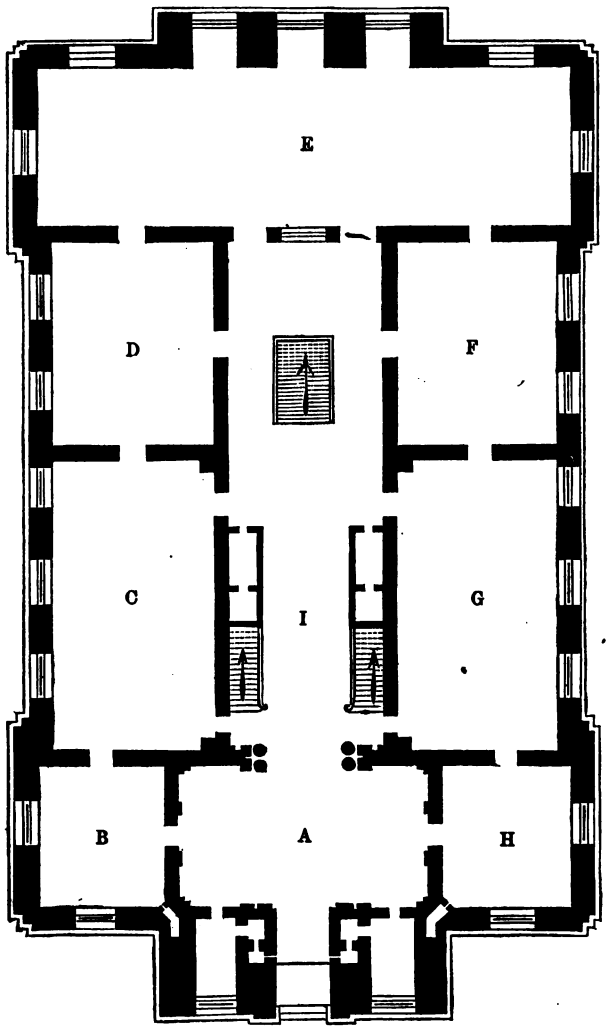
A. Woman's Chem. Lab., 27′ 6″ by 24′ 6″.
B. Balance Room, 14′ 6″ by 7′.
C. Reception Room, 11′ by 9′ 6″.
D. Industrial Chem. Lab., 24′ by 20′.
E. Microscopical Lab., 24′ by 20′.
F. Dark Room, Spectroscope.
G.G. Tool and Stock Rooms, 6′ by 6′.
H. Machine Tool Shop, 37′ by 20′.
I. Chipping and Filing Shop, 32′ 6″ by 20′.
J. Engine Room, 20′ by 7′ 9″.
K. Forging Shop, 39′ by 20′.
L. Pattern Weaving, 23′ 6″ by 20′.
M. Foundry, 41′ by 20′.
S. Carpentry and Joinery, Wood Turning and Pattern Making, 50′ by 20′.
N. Was Room, 13′ 6″ by 9′ 6″
O. Organic Chem. Lab., 1′ by 14′.
P. Special Work Room, 13′ by 9′ 6″.
Q. Store Room, 9′ 6″ by 6′.
R. Ice Chamber, 8′ by 5′.

BASEMENT FLOOR.



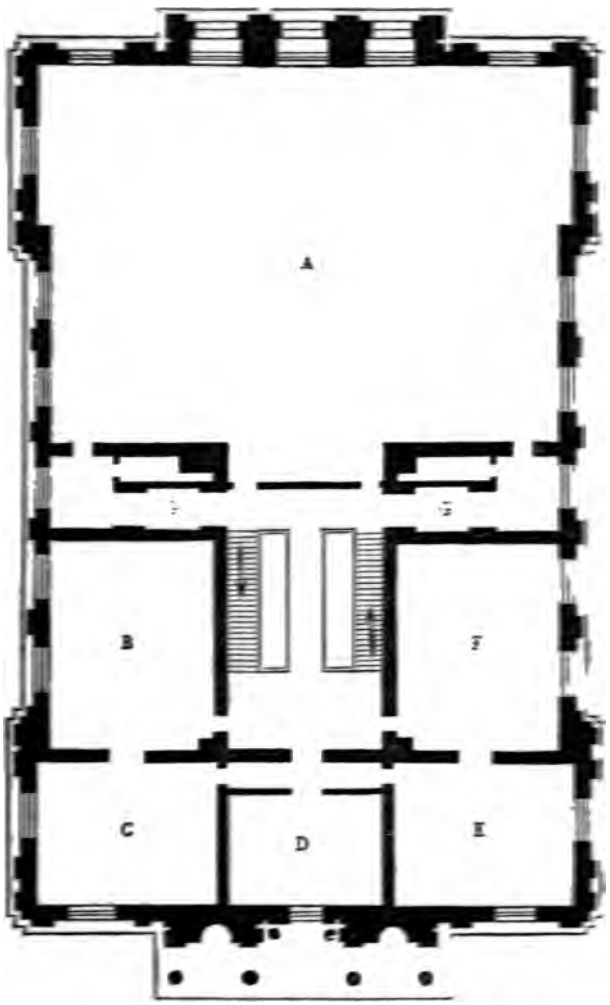
A. Professors' Chemical Laboratory, 25′ 0″ by 22′ 11″.
B. General and Qualitative Chemical Laboratory, 49′ 7″ by 34′ 0″.
C. Quantitative Chemical Laboratory, 35′ 8″ by 34′ 0″.
D. Quantitative Chemical Laboratory, 26′ 4″ by 24′ 0″.
E. Balance Room, 8′ by 13′.
F. Professor Wing's Private Laboratory, 16′ 0″ by 13′ 0″.
G. Mining Laboratory, 40′ 2″ by 27′ 10″.
H. Metallurgical Laboratory, 35′ 8″ by 34′ 0″.
I. Chemical Lecture Room, 49′ 7″ by 34′ 0″.
J. J. Mechanical Engineers' Laboratory, 25′ 0″ by 69′ 1″.
K. Daily Chemical Supply Room, 14′ 6″ by 12′ 0″.
L. Boiler Room, 15′ by 25′ 0″.

FIRST STORY FLOOR.



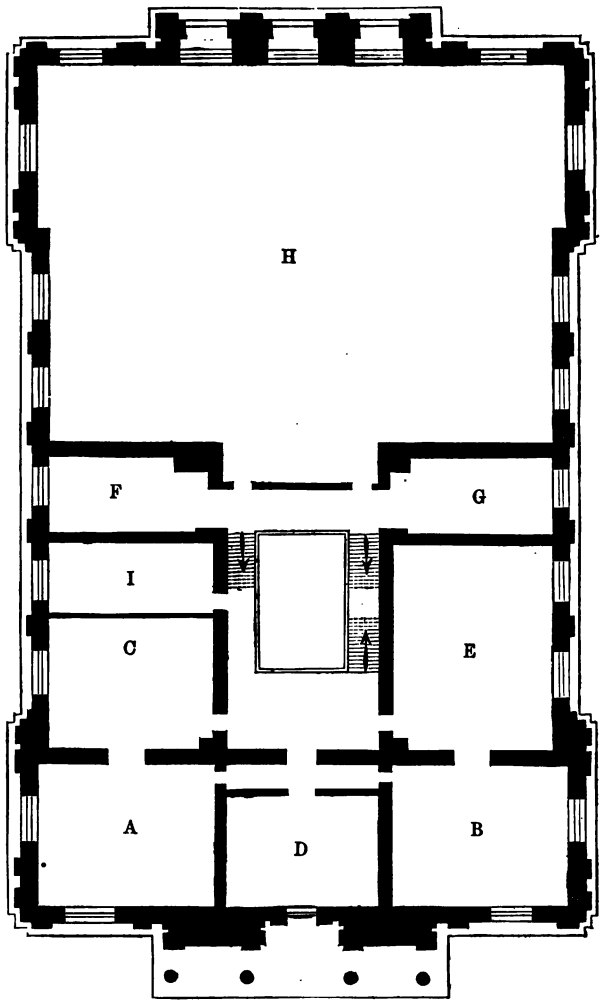
A. Entrance Hall, 42′ 2″ by 25′ 0″.
B. President's Office, 25′ 0″ by 22′ 11″.
C. Physical Lecture Room, 49′ 7″ by 28′ 3″.
D. Physical Laboratory and Apparatus Room, 35′ 8″ by 28′ 3″.
E. Physical Laboratory and Apparatus Room, 92′ 0″ by 27′ 10″.
F. Geological Lecture Room, 35′ 8″ by 28′ 3″.
G. Society of Arts Room, 49′ 7″ by 28′ 3″.
H. Secretary's Office, 25′ 0″ by 22′ 11″.
I. Stairway Hall, 87′ 2″ by 26′ 10″.

SECOND STORY FLOOR.



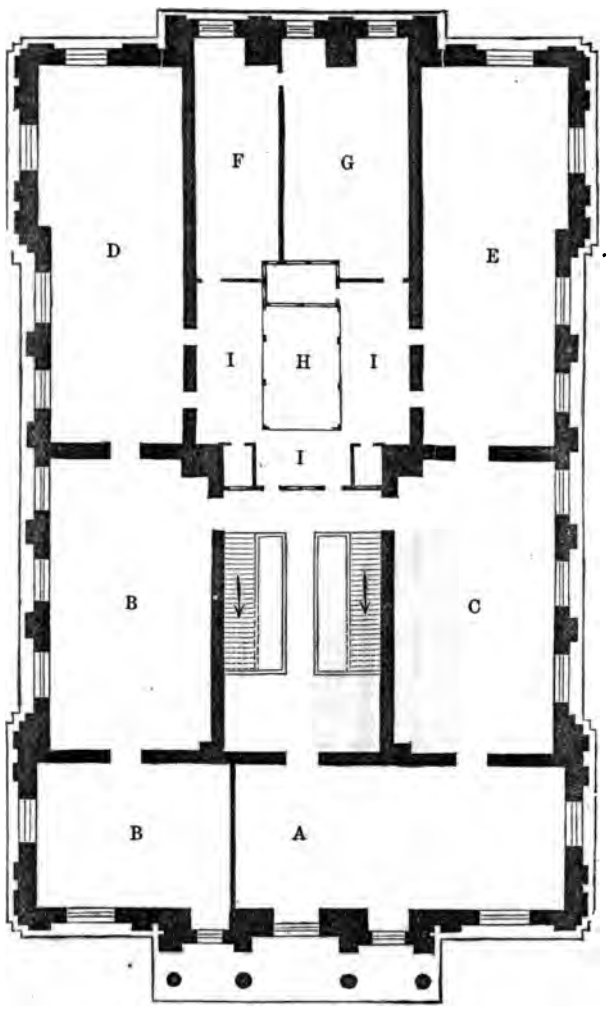
A. Huntington Hall. 78′ 1″ by 46′ 3″.
B. Mathematical Lecture Room. 30′ 3″ by 29′ 3″.
C. Civil Engineering Lecture Room. 23′ 2″ by 25′ 1″.
D. Modern Language Lecture Room. 20′ 3″ by 20′ 4″.
E. English Lecture Room. 23′ 1″ by 25′ 1″.
F. Mathematical and Astronomical Lecture Room. 24′ 1″ by 23′ 8″.
G. G. Passageways to Huntington Hall.

HALF STORY FLOOR.



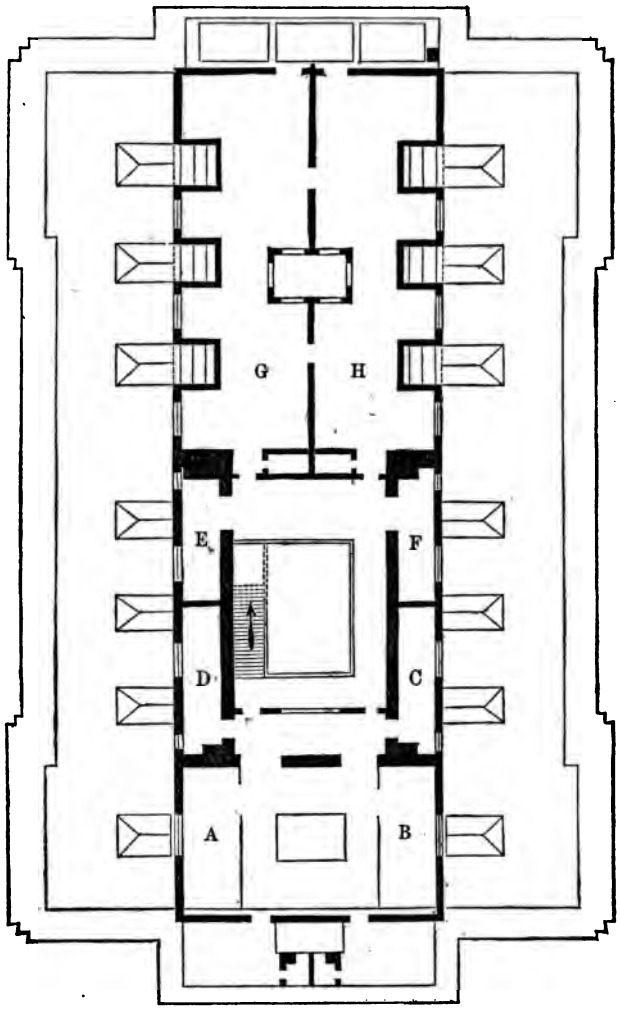
A. Architectural Museum, 32′ 2″ by 25′ 0″.
B. Architectural Library and Study Room, 32′ 2″ by 25′ 0″.
C. Architectural Museum, 28′ 3″ by 20′ 9″.
D. Natural History Lecture Room, 26′ 2″ by 20′ 6″.
E. Prof. Richards' Lecture Room, 34′ 9″ by 28′ 3″.
F. Prof. Atkinson's Study, 28′ 2″ by 14′ 2″.
G. Prof. Hunt's Study, 28′ 3″ by 14′ 2″.
H. Huntington Hall.
I. Prof. Howison's Study, 28′ 3″ by 14′.

THIRD STORY FLOOR.

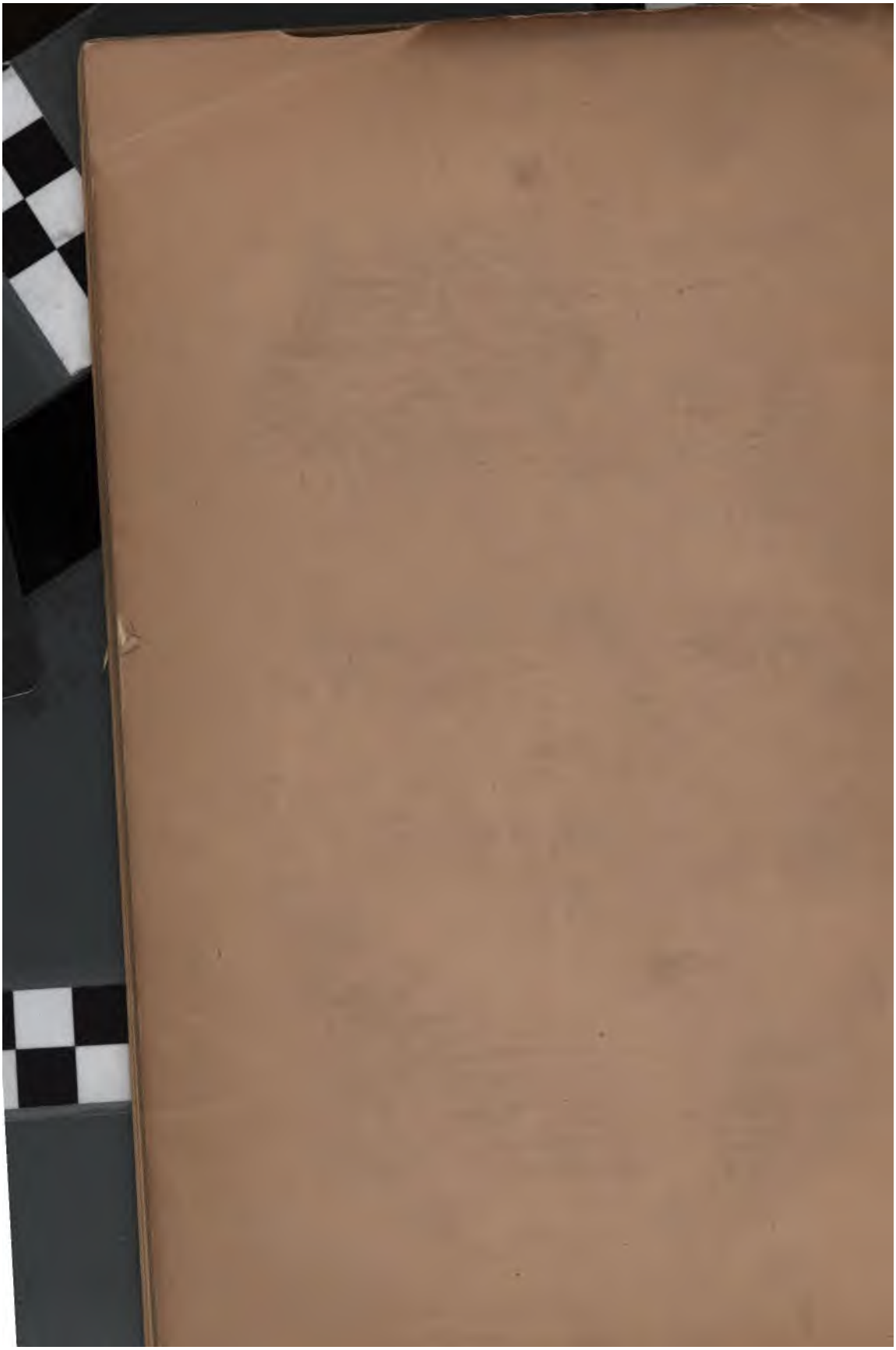


A. Reading and Study Room, 62′ 0″ by 25′ 0″.
B. B. Civil Engineers' Drawing Rooms, 49′ 7″ by 28′ 3″.
C. First Year's Drawing Room, 49′ 7″ by 28′ 3″.
D. Mechanical Engineers' Drawing Room, 65′ 5″ by 26′ 0″.
E. First Year's Drawing Room, 65′ 5″ by 26′ 0″.
F. Mechanical Engineering Lecture Room, 37′ 0″ by 17′ 0″.
G. Mathematical and Descriptive Geometry Lecture Room, 37′ 0″ by 28′ 0″.
H. Model Room, 21′ 0″ by 13′ 0″.
I. I. I. Passage. way

FOURTH STORY FLOOR.



A. Prof. Lanza's and Prof. Whitaker's Study, 24′ 5″ by 11′ 6″.
B. Prof. Henck's Study, 24′ 5″ by 11′ 6″.
C. Prof. Osborne's Study, 24′ 9″ by 7′ 6″.
D. Prof. Richards's and Prof. Nichols's Study, 28′ 0″ by 7′ 6″.
E. Instructors Handy and Waitt's Study, 21′ 6″ by 7′ 6″.
F. Prof. Ware's Study, 24′ 9″ by 7′ 6″.
G. Architects' Drawing Room, 65′ 5″ by 21′ 10″.
H. Lowell School of Design, 65′ 5″ by 21′ 10″.



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M4143

Mass. Institute of Technology.

President's Report

Dec. 12, 1883.

BOSTON:
J. S. CUSHING & CO., PRINTERS.
1884.

To the Corporation of the

Massachusetts Institute of Technology:

The nineteenth year of its active operation finds the Institute of Technology enjoying an unprecedented degree of prosperity. The good work done in the past is now bearing its fruit in public confidence and enlarged means of usefulness. I desire to emphasize my belief, at the very beginning of this report, that the great, and indeed remarkable, accessions which the Institute has received during the past three years have been due to no recent good fortune, but to the comprehensive wisdom and scientific enthusiasm of its founder and first President, to the judicious and faithful care of the corporation during the early days of its existence, to the zeal, devotion, and intelligence of the corps of professors and instructors, and preëminently to the faith and courage with which the standard of high scholarship was maintained during the times of darkness and despondency and almost of disaster.

STATISTICS OF ATTENDANCE.

The number of students at the present time is far in excess of the number attending at any previous period in the history of the Institute. The total of persons registered in all the departments and schools under the control of the corporation is 557, against an aggregate, last year, of 516. The gain, however, during the year has been substantially greater than would appear from

this comparison, inasmuch as a reduction of 31 has been purposely effected in the Lowell School of Practical Design, with the object of raising the standard at once of admission and of instruction within the school. Omitting the students of the Lowell School from consideration, the total number of students this year is 497, against 425 last year. But the real position of the Institute will be best reached by the further exclusion of the students of the School of Mechanic Arts. Deducting these, the number of students in the School of Industrial Science, as by the catalogue now passing through the press, is 443, against 368 last year, making an increase of 75, or more than 20 per cent. The following table exhibits the total number of students in the School of Industrial Science, from the opening of the Institute to the present time. The figures are exceedingly instructive as regards the forces which have operated to affect the attendance upon the school: —

Year.	No. of Students.
1865–66	72
1866–67	137
1867–68	167
1868–69	172
1869–70	206
1870–71	224
1871–72	261
1872–73	348
1873–74	276
1874–75	248
1875–76	255
1876–77	215
1877–78	194
1878–79	188
1879–80	203
1880–81	253
1881–82	302
1882–83	368
1883–84	443

STATISTICS OF EXAMINATIONS.

The results of the applications for admission to all classes of the School of Industrial Science, thus far in the current school year, and of the examinations had thereupon, may be stated as follows: —

31 were admitted without examination, either to the first year class, upon presenting certificates of clear admission to some college of reputable standing, or to the third year class, upon the presentation of diplomas of graduation from some degree-conferring institution, classical or scientific. 83 were admitted, upon examination, free of conditions; 52 were admitted, upon examination, with one condition imposed; 33 were admitted with two conditions; 6 were admitted with three conditions. 48 applicants were rejected upon examination. 27 were admitted as special students upon examination in the studies specially requisite to the partial courses which they proposed to follow.

The total number of applicants appears, therefore, to have been 280. Of those admitted upon examination 17 have not thus far entered the school. In some instances, in the case of applicants heavily conditioned, this has been due to the advice of the faculty, that a longer period be taken for preparation; in some, to a change of plans, to sickness or other causes. The total number of applicants rejected or voluntarily withdrawing was, thus, 65. Of those who were admitted upon examination as regular students, some have elected to become special students, mainly in the department of architecture.

STATISTICS OF RESIDENCE.

Not only is the aggregate attendance upon the Institute increasing, but scholars are coming to us from a constantly extending field, geographically. The students of

the School of Industrial Science are registered as from twenty-six States of the Union; in addition to which, students report themselves from Montana Territory, from the District of Columbia, and from four foreign countries. The tendency to a wide geographical extension of the constituency of the Institute is seen in a comparison of the respective proportions in which the successive classes of the regular departments are made up of students from within or from without Massachusetts. Thus, of the 29 members of the fourth year class, about to graduate, 25 are from Massachusetts, and but 2 from outside New England. Of the 37 members of the third year class, 30 are from Massachusetts, and 5 are from outside New England. Of the 61 members of the second year class, 42 are from Massachusetts, and 14 are from outside New England. Of the 145 members of the first year class, 82 are from Massachusetts, leaving 34 to come from other New England States, and 29 from outside New England. Eighteen States, besides the District of Columbia, the Territory of Montana, and two foreign countries, are represented in the membership of this class.

Of the total number of 272 students of the regular courses, in all classes, 179 are from Massachusetts, 43 from other New England States, and 50 from outside New England. Of the total number of 443 students, including special students, 288 are from Massachusetts, 57 from other New England States, and 98 from outside New England. Eight Southern States appear on our rolls, with an aggregate of 22 students.

The following table shows the number of students, of each specified class, from each State or Territory or foreign country: —

	Students of the Regular Courses.					Special Students	Aggregate School of Industrial Science.
	4th Year	3d Year	2d Year	1st Year	Total Students of the Regular Courses.		
Massachusetts	25	30	42	82	179	109	288
Maine	1	1	1	13	16	3	19
New Hampshire	1		1	10	12	5	17
Connecticut			1	7	8	3	11
Vermont			2	3	5	1	6
Rhode Island		1		1	2	2	4
Total New England	27	32	47	116	222	123	345
New York		1	2	4	7	8	15
Pennsylvania		1	1	3	5	3	8
New Jersey						2	2
District of Columbia				2	2	1	3
Ohio			1	1	2	7	9
Illinois	1	1	4	3	9	5	14
Indiana						2	2
Wisconsin						1	1
Iowa			1	3	4		4
Minnesota			1	2	3	2	5
Kansas			1	1	2		2
Nevada				1	1		1
California						1	1
Montana				1	1		1
Delaware						1	1
Maryland	1			2	3	6	9
Virginia				2	2	1	3
North Carolina		1	1		2	1	3
South Carolina						1	1
Kentucky		1	1		2		2
Missouri				1	1	1	2
Georgia				1	1		1
Dominion of Canada				2	2	3	5
Scotland			1		1		1
South America						1	1
India						1	1
Total	29	37	61	145	272	171	443

PROPORTION OF OLD AND OF NEW STUDENTS.

The table following exhibits, for each year of the School's history, the distribution of the total number of students among two classes: first, those students remaining whose names are found upon the catalogue of the year preceding that for which the statement is given; and, secondly, those students whose names appear as new names upon the catalogue of the year to which the statement relates: —

Year.	(1) Total No. of Students.	(2) No. of Students in the Catalogue of the previous year who remain in the Institute.	(3) No. of New Students entering before issue of Catalogue.	(4) Of those in column (3) the following No. were regular first year Students.	(5) No. of New Students not of the regular first year class.
1866–67	137	34	103	58	45
1867–68	167	79	88	54	34
1868–69	172	82	90	50	40
1869–70	206	90	116	63	53
1870–71	224	109	115	71	44
1871–72	261	122	139	82	57
1872–73	348	173	175	112	63
1873–74	276	171	105	59	46
1874–75	248	159	89	35	54
1875–76	255	139	116	65	51
1876–77	215	130	85	31	54
1877–78	194	96	98	47	51
1878–79	188	99	89	34	55
1879–80	203	102	101	34	67
1880–81	253	121	132	62	70
1881–82	302	136	166	86	80
1882–83	368	173	195	114	81
1883–84	443	231	212 *	140 †	72

* This number differs from the number previously stated as having been admitted thus far in the school year, 1883–84, by three, being the number of former students of the Institute returning after an absence more or less protracted.

† In addition, five students are repeating the first year.

It will appear from the foregoing table that, since 1879, there has been a steady and rapid increase in the number of students remaining over from year to year; the number for 1879 being 102; for 1880, 121; for 1881, 136; for 1882, 173; for 1883, 231. That the rate of increase of the number of new students has in some of these years even exceeded that of the number of students remaining over, is not due to any greater tendency to drop out of the school, but to the large absolute increase in attendance.

PROPORTION OF REGULAR AND OF SPECIAL STUDENTS.

Still another table which has been prepared exhibits both the absolute number of regular and of special students, as by the catalogue of each successive year, and also the proportion existing between these two classes:—

Year.	No. of Regular Students.	No. of Special Students.	Total No. of Students.	Percentage.	
				Regular.	Special.
				Per cent.	Per cent.
1865–66	64	8	72	89	11
1866–67	110	27	137	80	20
1867–68	124	43	167	74	26
1868–69	105	67	172	61	39
1869–70	125	81	206	71	29
1870–71	143	81	224	64	36
1871–72	180	81	261	69	31
1872–73	235	113	348	68	32
1873–74	182	94	276	66	34
1874–75	170	78	248	69	31
1875–76	182	73	255	71	29
1876–77	134	81	215	62	38
1877–78	117	77	194	60	40
1878–79	103	85	188	55	45
1879–80	110	93	203	54	46
1880–81	140	113	253	55	45
1881–82	164	138	302	54	46
1882–83	219	149	368	60	40
1883–84	272	171	443	61	39

It is gratifying to note a tendency within the past two years to an increase in the proportion of students attending regular courses. This expression, however, should not be taken as implying that it is in any way desirable that the class of special students should disappear from our catalogue, or should be reduced to insignificant proportions. Among the special students have always been some of our best and most promising scholars; and many of the most marked successes of this School of Industrial Science have been achieved in the training and preparation for active life given to those whose age at the time of entrance, or whose family circumstances or pecuniary condition, or whose plans for life, would not have permitted their taking the full regular course in any of the departments of the school. It has always been the policy of the faculty to encourage and promote the admission of special students of this class, especially in the case of those who, having entered upon active life with inadequate preparation, have had the courage and the self-denial to break abruptly off from gainful occupations and come hither for two years, or, it may be, for a single year, with a view to accomplish themselves in those particular respects in which they were most deficient. Moreover, among the special students of the Institute are always found some who are doing their best to qualify themselves as regular students by making up existing deficiencies of preparation.

THE CORPS OF INSTRUCTORS.

The instructing staff of the Institute has necessarily varied with the fortunes of the school and with the number of students in attendance, though not with anything approaching strict correspondence. The following table exhibits severally for each school year the number of professors, of assistant professors, of instructors, and of assistants since the opening of the school: —

Year.	Professors.	Assistant Professors.	Instructors.	Assistants.	Total.
1865–66	10				10
1866–67	12		2		14
1867–68	12	1	2	2	17
1868–69	13		6	1	20
1869–70	16	1	6	2	25
1870–71	18	2	7	5	32
1871–72	21	2	11	1	35
1872–73	23	2	9	1	35
1873–74	20	3	10	4	37
1874–75	20	3	7	3	33
1875–76	23		6	8	37
1876–77	21		4	10	35
1877–78	20		3	14	37
1878–79	18		7	12	37
1879–80	16		7	8	31
1880–81	15	2	6	7	30
1881–82	17	3	6	11	37
1882–83	16	3	10	11	40
1883–84	15	8	15	10	48

The appointment, during the year, of Dr. Sedgwick, as Assistant Professor of Biology, of Dr. Norton, as Assistant Professor of Organic Chemistry, of Mr. Wells, as Assistant Professor of Mathematics, of Mr. Swain, as Assistant Professor of Civil Engineering, and of Mr. Crosby, as Assistant Professor of Mineralogy and Lithology, has greatly strengthened the instructing staff.

COURSES OF INSTRUCTION.

Regarding the various courses and departments of the School, it may be said that the fortunes of the Institute, the changing conditions of the national industry, the varying tastes and predilections of individuals, and, to a certain extent, doubtless, the tendency of students to move together, have combined to produce not a little fluctuation in the numbers of students within the several courses and departments. The following table exhibits the number of persons who have graduated within each of the several courses at each successive year since the first diplomas were conferred in 1868: —

Year.	I. Civil Engineering.	II. Mechanical Engineering.	III. Mining Engineering.	IV. Architecture.	V. Chemistry.	VI. Metallurgy.	VII. Natural History.	VIII. Physics.	IX. General Courses.*	Total.
1868	6	1	6						1	14
1869	2	2			1					5
1870	4	2	2		1				1	10
1871	8	2	5		2					17
1872	3	1	5		3					12
1873	12	1	3	1	7				1	25
1874	10	4	1	1					2	18
1875	10	7	6	1	1			1	2	28
1876	12	8	7		5	1	2	3	3	41
1877	12	6	8	4	2					32
1878	8	2	2	3	3				1	19
1879	6	8	3	1	3		1	1		23
1880	3		3		1				1	8
1881	3	5	6	3	8		1		2	28
1882	2	5	5	3	6		1	1	1	24
1883	3	7	4	1	3					18
	104	61	66	18	46	1	5	6	15	322

The following table exhibits the distribution of the 127 regular students in the three upper classes of the Institute among the several courses, the choice of courses being made, it will be remembered, only at the close of the first year of study: —

	I. Civil Engineering.	II. Mechanical Engineering.	III. Mining Engineering.	IV. Architecture.	V. Chemistry.	VII. Natural History.	VIII. B. Electrical Engineering.	IX. General Courses.	Total.
4th year class	5	6	8		10				29
3d year class	6	8	9	2	5	1	5	1	37
2d year class	10	19	10	3	6		13		61
	21	33	27	5	21	1	18	1	127

* This includes not only the General Courses now existing, but the former Science and Literature Course, and the former Elective Course.

The regular students of the first year now number, as by the forthcoming catalogue, 145.

THE WORK OF SPECIAL STUDENTS.

The 171 special students in the School of Industrial Science cannot be classified systematically, but the following table exhibits the number of special students pursuing each particular branch of study, according to the attendance papers filed by them, and approved by the Faculty:—

NUMBER OF SPECIAL STUDENTS ATTENDING EXERCISES IN THE FOLLOWING DEPARTMENTS OF STUDY OR PRACTICE.

Architecture	28	German	75
Astronomy	8	Mathematics	76
Assaying	7	Mechanics	13
Biology	9	Mechanical Engineering	26
Botany	1	Metallurgy	10
Chemistry	76	Metallurgy Laboratory	1
Civil Engineering	16	Military Drill	20
Drawing	37	Mining	3
Descriptive Geometry	6	Mining Laboratory	5
English	60	Physics	58
French	11	Shop Work	40
Geology	8	Zoölogy	2

Total number of entries, by special students	596
Total number of special students	171
Average number of entries	3.5

NEW DEPARTMENTS OR COURSES: ELECTRICAL ENGINEERING; PREPARATION FOR THE STUDY OF MEDICINE.

Among recent developments, in the matter of the courses of instruction in the Institute, especially deserve to be mentioned the following: The establishment last year of a course (VIII. B) in Electrical Engineering, under the special charge of the Professor of Physics, intended to

meet the rapidly increasing demand for persons qualified to conduct the great variety of business enterprises which the remarkable discoveries in electrical science have called into being within the last few years, and, secondly, the institution during the present year of a course (VII. B) in preparation for the professional study of medicine. Regarding the latter, it should be said that its germ has long existed in the course relating to natural history, which, under the charge of Professor Ordway, has offered no small facilities for the special preparation of young men who had it in contemplation to enter any one of the medical schools of the country upon leaving the Institute. The lack, however, of an adequate biological laboratory, and the great variety and exacting nature of the duties charged upon Professor Ordway, or assumed by him in his unstinted zeal and devotion to the interests of the school, have heretofore prevented any considerable actual development in this direction. The appointment of Dr. Sedgwick as Assistant Professor of Biology, and the assignment of a commodious and convenient laboratory to the work of instruction under this head have, since the beginning of the present school year, brought strongly out the possibilities of such a course in the Institute, and already a number of students have enrolled themselves in connection therewith. I feel assured that this is destined to be among the most useful of the departments of instruction in the future; and it is gratifying to observe a great degree of cordiality among the most eminent physicians and professors of medicine in Boston and Massachusetts towards the proposed scheme. The essence of the course preparatory to the professional study of medicine, as drawn up by the Faculty, consists of instruction and laboratory practice in chemistry, in physics, in general biology, and in physiology. The cultivation of the perceptive powers, the systematic practice of the art of observation, the use of instruments of precision, the early familiarity with the structure, habits, and workings of liv-

ing objects, which are involved in this course, must be conceded to afford the kind of training best suited to enable the scholar to pursue the subsequent study of medicine, with the greatest advantage, and cannot fail to prove of peculiar value to the physician in his professional practice.

PROGRESS IN THE LONGER ESTABLISHED COURSES.

Throughout the longer established courses of the Institute, the same high standard of study and laboratory practice which has been maintained from the first, even against poverty and inadequacy of means, still characterizes the work of the school. Indeed, with the increasing knowledge of the needs of instruction on the part of teachers, due to their experience with successive classes, with the enlarged facilities and improved apparatus afforded by the liberal policy of the Corporation, and with the higher organization and more perfect systemization which are sure to be achieved in the intelligent prosecution of any service, that standard may confidently be claimed to have risen steadily from year to year. Perhaps no better illustration could be offered of this than in the very remarkable development of the chemical department. The work which formerly was carried over four years of study and laboratory practice, is now completed in three. This has not been effected by any abridgment of the field of work, any scrimping of experiment or practice, or any lowering of the requirement of performance. Nor, on the other hand, has it been effected by any greater tax upon the time of the students, or any greater strain upon their nervous force. It has been effected, as suggested, solely by the more perfect organization and systemization of the service. The entire fourth year of the chemical course is now left open to a class of work which, ten years ago, even the ambition of the devoted professors in this department did not allow them to contemplate as practicable. And what has

been achieved in this department has been in greater or less measure achieved in other departments of the school.

THE NEW LABORATORIES.

The feature which especially characterizes the Massachusetts Institute of Technology, in contrast with other scientific and technological schools, is the predominance of laboratory, shop, and field practice, experiment, and research. These are used at every point, where it is found practicable, to supplement, to illustrate, and to emphasize the instruction of the recitation or lecture room. Especially have the departments of mechanical engineering and of applied mechanics had their opportunities for experiment largely increased during the year. Twelve months ago the department of applied mechanics was confined to a single small room, in which, however, has been carried on some of the most original and useful work ever done in this line of research; the laboratory of steam engineering found its space only in the dark hall-way of the basement of the Rogers Building, without a partition or even a screen to protect its one small engine and limited apparatus; while the machine shops, established in 1876 by the enlightened wisdom of President Runkle, had the use of only a part of the low brick annex, where, often in the same room, materials, processes, and products were necessarily crowded together, without the facilities either for nice work or for orderly arrangement. To-day, the department of applied mechanics has expanded until it occupies more than three times its former space. The department of mechanical engineering has the use of laboratories adequate not only to its present needs, but to a very large future increase; while, in addition to the small but excellent engine presented some years ago by the generosity of Mr. George B. Dixwell, the department has now the use of two powerful engines of improved modern types, always available for purposes of instruction

and experiment. The mechanic art shops have been, within the past few weeks, removed to the new buildings on Garrison Street, where, in light and commodious rooms, covering twenty thousand square feet of floor surface, have been placed forty carpenter's benches; thirty-seven wood lathes, on benches which can, also, be used for carpenter work; thirty-two blacksmith's forges, with anvils and vises; twenty-two engine and fifteen speed lathes, for working metal, with a full equipment of planers, shapers, milling machines, and other apparatus, from the best machine shops of the country.

Exclusive of the members of the School of Mechanic Arts, ninety-five students now receive instruction in the ordinary mechanical arts. In the belief that nothing can surpass this species of instruction in value, not only for the uses to be made of the knowledge and aptitude acquired, but also for the training of the perceptive powers, for the development of executive faculty, and of practical, economic sense, all possible extension will be given to this branch.

The Rogers Physical Laboratory has shared in the opportunity for expansion afforded by the completion of the New Building, of which it will occupy the first story nearly entire, with a lecture room for two hundred students on the second floor. The rooms assigned to the physical department are now being fitted up in the most thorough and comprehensive manner, with reference both to elementary instruction and to advanced work and original research in heat, light, sound, and electricity. The number of laboratory students in physics is as follows: second year, 19; third year, 40; fourth year, 18. The number attending the lectures given in the second year is 110.

The introduction of a course of instruction and research in ventilation, for the benefit of the students in physics, in architecture, and in civil engineering, has been an interesting feature of the last year.

For chemical practice, the facilities of the institution,

by the completion of the Kidder laboratories, founded by the late Jerome G. Kidder, of Boston, have been greatly extended.

It may be long before any American institution will be able to offer opportunities for the highest kind of research, such as are afforded in the laboratories of the ancient universities of Germany; but I have no hesitation in saying that during the first four years of chemical study and practice, the student cannot find in any school of the old world facilities superior to those which the friends of the Institute of Technology have provided.

The new laboratories contain desks for 450 students in chemistry: 288 in the laboratory of general chemistry, 108 in the analytical laboratory, 30 in the laboratory of organic chemistry, making 426; while the remaining 24 are found in 5 small private laboratories. There are at the present time 272 students in chemistry, of whom 189 are in the first year, 29 in the second year, 25 in the third year, and 29 in the fourth year. Of the fourth-year students, 12 work in the laboratory of organic chemistry, and 13 in the laboratory of industrial chemistry. The Kidder Chemical Lecture Hall in the third story has a seating capacity of two hundred.

THE MINING AND METALLURGICAL DEPARTMENTS.

The Mining and Metallurgical laboratories of the Institute have long been recognized as possessing a merit almost unique for the purposes of instruction. They have been built up, so to speak, from the ground, under the most painful restrictions as to space and as to available means, by the devotion, the self-sacrifice, and the intelligence of a graduate of the Institute. A high European authority has recently pronounced the metallurgical laboratory of the Institute the first in the world for purposes of instruction. Probably the most pressing present need of the Institute, after the magnificent endowment this year provided for the

chemical and mechanical engineering departments, is that of a new mining and metallurgical laboratory, in which the inventive talent and the professional ambition of Professor Richards may have scope to develop themselves fully in the building up of machinery and apparatus for this most important service. A school which has already done so much, with so little, in promoting the education and training of young men to direct and control the development of our mineral resources, should not be denied the means for realizing its largest possible usefulness in this direction.

THE DEPARTMENT OF INDUSTRIAL CHEMISTRY.

The Corporation have already given expression to a desire that the department of Industrial Chemistry should receive a rapid development, to enable it to meet the increasing demand from the various manufacturing industries of New England and of the country. That this department has in the past done excellent work is attested by the positions attained by the graduates of the School in connection with many of the largest industrial establishments of the United States; but its usefulness has been restricted heretofore not only by the lack of laboratory facilities, but also by the numerous and exacting duties which the absolute needs of the school have imposed upon the head of that department. From many of these the re-arrangement and re-assignment of duties, both of instruction and of supervision, have already, within the past two months, relieved Professor Ordway. The erection of a laboratory of industrial chemistry, for which the land purchased during the last year by the Corporation would amply suffice, will be a pressing necessity within the near future.

MATHEMATICAL INSTRUCTION.

Mathematical studies must always remain in a high sense the most vital part of any school of pure or applied science.

The success of the departments of chemistry, of physics, of metallurgy, and even of biology, is dependent, in a large degree, upon the discipline acquired in the mathematical recitation-rooms as well as upon the knowledge of mathematical principles there obtained. In this branch of instruction the Institute is, as it has always been, exceptionally strong. The requirements of such professional courses as are alone fit to be pursued in a school of the highest grade cannot fail to be found somewhat onerous and painful by students who are not gifted with natural mathematical aptitudes, nor is it easy for a scientific faculty greatly to qualify those requirements without lowering the standard of attainment and accomplishment.

INSTRUCTION IN THE MODERN LANGUAGES.

Instruction in the Modern Languages becomes, of necessity, a very important part of all the regular courses, and of any extended special course, in a scientific or technological school. It is gratifying to report a marked degree of success in this department of instruction, within the Institute. The ability to read easy French is now required as a condition of entrance to all the regular courses, and the study of that language is pursued throughout the first year by all regular students, except such as may be individually excused, as having previously acquired the requisite degree of knowledge and proficiency. After the first year this study becomes elective, except that in the fourth year of the course in architecture, the further study of French is required. The study of German is begun at the opening of the second year by all regular students, and is pursued as a required exercise, except in the case of students individually excused, until the close of the third year, after which it becomes elective. Spanish and Italian are elective studies throughout the second, third, and fourth years.

The total number of students of all classes in French is 145 ; in German, 167; in Italian, 2.

At the beginning of the last academic year, elementary French was introduced as a required study into the second year of the School of Mechanic Arts.

THE DEPARTMENT OF MECHANICAL ENGINEERING.

Upon the retirement of Professor Channing Whitaker, after eight years of laborious and devoted service, from the chair of Mechanical Engineering, Professor Lanza, at the request of the Corporation, assumed the charge of that department in addition to his own, viz., Applied Mechanics. Professor Lanza's conduct of this most important department — now become the largest in the Institute — has been marked by singular force, comprehensiveness, and soundness of judgment. The four instructors in mechanical engineering, three of whom are graduates of the Institute, constitute an exceptionally strong staff, and the increased facilities put at the disposal of the department give assurance of a development commensurate with the rapidly increasing demands made upon it by the industries of the country.

THE GENERAL COURSES.

I have spoken of recent developments in the courses of instruction in the Institute, especially the establishment of the course of electrical engineering, and the extension of the instruction in natural history, as a means of preparation for the subsequent professional study of medicine. There is still another direction in which the Faculty strongly desire to secure an early extension of the usefulness of the school, namely, through giving unity and vitality to the courses now known on the catalogue as General Courses, A, B, and C, which have for their special object the preparation of young men for active business life, through studies

which are of a predominantly scientific character, yet not directed toward any one of the distinctly scientific professions. Almost from the opening of the school, courses have been arranged with reference to this object; but the exacting demands made by the engineering and other technical departments upon the very limited resources of the Institute, have, in the past, prevented instructors from giving to these courses the degree of time and effort necessary to secure their proper development. Moreover, as the primary object of the Institute has been known to be technical education, it has not been found easy to attract the required degree of attention to the projected branches of study, on the part of pupils or their parents.

Somewhat more than a year ago, the Faculty, with the approval of the Corporation, established the three general courses above referred to, recommending them in the case of young men whose purpose it is to become merchants, manufacturers, or bankers, and who desire a preparation for active life, liberalizing in its tendencies, but without any influence to alienate the student from the ideas, tastes, and habits which are appropriate to practical business pursuits. Each of the courses thus instituted contains a solid body of scientific study and of scientific field or laboratory work. In the first, physics, with the requisite mathematics, predominates among the scientific studies; in the second, chemistry, with the closely related sciences of botany and physiology; in the third, geology, with botany and zoölogy. While each of these courses contains thus a great deal of scientific study and practice, more attention is devoted to the study of language, literature, history, political economy, business law, and industrial science than would be compatible with the requirements of the purely professional courses. The time which in the latter is necessarily given to the special technical study and work essential to the architect, the engineer, the naturalist, or the chemist, is, in the courses under consideration, assigned to more general studies,

which are of a nature to enlarge the views and enrich the life of the man of business.

The period which has elapsed has not been sufficient to test the suitableness of the courses thus projected to meet the demands of the community; but with the improved facilities of instruction at the command of the Institute, I cannot doubt that the opportunities thus offered for an education which shall combine both practical and liberal tendencies will be made use of in a rapidly increasing degree.

THE EDUCATIONAL INFLUENCE OF SCIENTIFIC AND TECHNOLOGICAL STUDIES.

While it must be conceded that force of expression and facility in the communication of thought are best to be acquired through the philosophical, dialectical, and rhetorical studies and exercises which in the main compose the curriculum of the older institutions of our country, I believe it to be equally true that the faculties of clear perception, of careful discrimination, and of just generalization are developed by the study of natural history, of chemistry, of physics, as they can be through no other educational means.

There is, moreover, a consideration of not a little moment, in this connection, which may fairly influence the minds of parents and of preparatory teachers, in deciding between the traditional and the new education. This consideration I will, without the slightest wish to undertake any disparagement of classical studies, now venture to indicate.

It is a fact, too palpable to be questioned, that the large and undoubted advantages of the traditional system of education are secured by those students whose aptitudes and tastes give them an interest in the pursuit of language and literature, at a great and unspeakable sacrifice on the part of that other and not inconsiderable

class of young men whose faculties and dispositions do not prepare them for, or incite them to, studies of this character. It is a familiar feature of classical colleges that large numbers of students, who are by nature neither vicious nor idle, not finding the wants of their minds satisfied by the studies to which they are directed, relinquish, at a very early date in their collegiate career, all scholarly ambition, and come, with more or less reluctance, to accept the part of doing nothing well, contented to be known as poor scholars, frequently rebuked and harassed by their instructors and their parents on account of their deficiencies, and aiming no higher than to pass the periodical examinations which are to determine the question of their continuance as members of the college. Surely this is a poor preparation for life, at least for practical business life, where success is to be gained far less by talent or acquirement than by promptitude, by punctuality, by industry, by self-respect and by strict attention to duty. It is making no unseemly boast and offering no unfair comparison, to say that students of that class are exceedingly rare in this school. The idle student is hardly known here. The painful task of harassing and menacing scholars, who are such only in name, who have, as scholars, neither ambition nor self-respect, is one from which the Faculty are almost entirely relieved. What with the variety of courses here presented to the student for his own free election, what with the interest which the youthful mind always finds in one or another kind of laboratory practice or field work, it is seldom that a student fails to give, without compulsion, even without admonition, all the time and effort to his own chosen course which his instructors deem right and proper. Differences, and great differences, indeed, exist as to the degree of success attained by our scholars. Yet it is surprising to observe how far the opportunity to make choice of the kind of work which shall be done goes to make up for the deficiencies which appear when a large body of students are

subjected to one and the same test of scholarly ability or performance. Young men who exhibit no inclination or aptitude whatever for linguistic or philosophic studies, are often found to take the deepest interest in natural history, in chemistry, or in mechanics; to have remarkable aptitude for manipulation, and to possess excellent powers of perception, discrimination, and judgment.

Not infrequently one who, if compelled to pass through long courses of classical, rhetorical, and dialectical exercises, would have had a thoroughly unhappy career, finding nothing in his daily tasks to interest his mind or call out his powers, feeling himself continually at a disadvantage in comparison with others, and soon, probably, sinking into that most unfortunate condition for a young man, of accepting a low standard of performance, is found among our brightest, most apprehensive, most enthusiastic, and most successful scholars.

A generation ago it was the accepted theory of educators, generally, that instruction, to be most effective, should cross the grain of the youthful mind; that if disinclination were shown towards any particular study, the teacher should catch at this as his welcome clue; and that the scholar should thereafter be practised and drilled, for his mind's good, against his indifference, his dislike, and even his repugnance, until he should learn to do well and freely that for which he had originally the strongest inaptitude. In a word, indisposition towards any kind of mental exercise was to be dealt with like a sinful inclination; war was to be made upon it until it should be conquered.

Not only a better observation of life, but the study of physiological psychology has led the educators of to-day to a widely different view of the office of instruction. It is now generally admitted that it is the first duty of the teacher to ascertain the true bent of the youthful mind, and that, so far as practicable, instruction should be made to conform thereto; that the successful teacher is not the

one who compels the scholar to do, at the last, reasonably well that which he was at the first least disposed to do, but the one who brings the scholar to do, in the fullest degree and in the most perfect manner, that for which he has the greatest aptitude, leading him, with ever-increasing freedom and pleasure of work, in the ways which nature has pointed out; that in any other system of training there is enormous and irreparable loss of nervous force and moral enthusiasm, with a result certain to be lower and less desirable than under the system which seeks to develop to their highest efficiency the native powers of the mind.

These remarks have been suggested by reference to the so-called General Courses which have been described. I feel a strong assurance that an increasing appreciation of the superior advantages of a predominantly scientific and practical education, with a modicum of literary and philosophical training, in the case of all young men who have not a decided taste and aptitude for the traditional studies of the American College, will secure a steady, rapid growth of the Institute upon this side.

MILITARY DRILL.

One other branch of instruction requires to be mentioned here; namely, Military Drill. As a beneficiary under the grant of the General Government, the Institute is bound to give instruction in military tactics. It would be entirely practicable, and perhaps not unfair, to reduce this branch of our work within very narrow dimensions, as is done in many institutions which stand in the same position in this respect. But the action of the Corporation and the Faculty in the past has made this a substantial and relatively important department of the school. The entire first-year class, with the exception of such as are specifically excused for physical disability or other cause, undergo a thorough training in military tactics, including

the evolutions of the battalion. This department is now under admirable control, at the hands of Gen. Hobart Moore, the recently appointed instructor. Through means of the drill thus afforded, our young men, coming to the school from every variety of conditions, acquire the instinct of subordination, the power of cohesion, promptitude and precision of movement, and habits of mind as well as of physical bearing which cannot fail to be useful in a high degree.

WOMEN IN THE INSTITUTE.

As early as 1867, among the Lowell Free Lectures given by instructors of the Institute, were two courses in chemistry, by Professors Eliot and Storer, open equally to both sexes. In 1868, laboratory exercises were substituted for lectures, upon the same condition. This continued, with the exception of one year, until 1877. In the latter year, the erection of the low brick annex on the grounds of the Institute furnished the space requisite for a separate laboratory for women, and the sum of $2500 was furnished by the Woman's Education Association to provide instruments and apparatus for instruction in advanced chemistry, mineralogy, botany, and industrial chemistry. In November of that year the laboratory was opened to students. In the seven years that have intervened, the whole number of students in this laboratory has been 102, more than half of whom were teachers at the time of their entrance into the laboratory, or were fitting themselves for that profession.

When the erection of the new building of the Institute was last year determined upon, the Corporation accepted the gift of $8,000 from certain associations and individuals interested in the object, as a means of providing, in the contemplated chemical laboratories, adequate space and

facilities for the instruction of women. The completion of these laboratories of necessity supersedes the separate laboratory which had been so long maintained, largely through the zeal and self-devotion of Mrs. Ellen H. Richards, herself a regular graduate of the Institute, who has for seven years given instruction, several hours of each school day, without any compensation for her services. The Corporation have already granted the full degree of the Institute to five women, who have completed one or another of the regular courses of study and research. The number of women at the present time with the School, as regular or special students, mainly in the departments of chemistry and biology, is eleven. Two of these are members of the senior class, in good standing, and will offer themselves next summer as candidates for a degree. The "Margaret Cheney Reading Room," named in memory of one of the former scholars of the Institute, which is now being fitted up on the third floor of the new building, will afford the students of this sex adequate facilities for retirement and rest in the intervals of recitation and laboratory work.

THE SCHOOL OF MECHANIC ARTS.

I have thus far spoken only of the School of Industrial Science, which forms, and will doubtless always form, the predominant part of the Institute of Technology; which, indeed, in the view of most persons, is the Institute. Two subsidiary schools have, however, been established, which deserve the confidence and support of the Corporation. The School of Mechanic Arts, founded in 1876, has fully justified the efforts and sacrifices involved in its establishment. It has given a useful education and training to considerable numbers of young men; it has paid its own expenses; and it has gone far to meet the cost of maintaining mechanical laboratories and workshops for the benefit of the students in

engineering and architecture in the School of Industrial Science. The attention of educators in all parts of the country is being increasingly drawn to the need of this species of education and training for multitudes of young men whose financial conditions or plans for life do not allow them to contemplate a professional career; and, much as our School of Mechanic Arts has already contributed to the credit and reputation of the Institute, it is, I believe, destined to do so in a far higher manner in the immediate future, when it shall be recognized as the prototype of great numbers of schools of this class, forming an important integral part of the educational system of the country. It is a question which will probably arise during the present year, whether the course of instruction in this school may not advantageously be lengthened to three years.

THE LOWELL SCHOOL OF INDUSTRIAL DESIGN.

The Lowell School of Industrial Design, established in 1872 by the Trustee of the Lowell Institute, has, from its foundation, filled, and now fills, a position of great usefulness. The opportunities it offers for acquiring taste and skill in composition and design, with reference to the industrial arts, have been a great boon to large numbers of young persons. Graduates of this school have had, on the whole, a remarkable degree of success in their chosen avocations, and the number of applicants for its privileges is continually increasing. This has allowed an advance at once in the standard of requirement for admission, and in the standard of performance within the drawing rooms of the school.

COMMITTEES OF VISITORS.

The appointment of Committees of Visitors, under the recently adopted Rules of the Corporation, promises to be of great service. Already, the good influences of the new

force thus set in operation have been felt throughout the school. Instructors and students alike have been gratified and encouraged by the presence of members of the Corporation at recitations, lectures, and laboratory practice, while several suggestions of manifest practical value have been offered as the first result of this visitation.

THE SOCIETY OF ARTS.

The Society of Arts has, through the past year, continued its course of usefulness in the diffusion of scientific knowledge and in the discussion of new discoveries and inventions applicable to the arts of life. The Executive Committee, under the chairmanship of Mr. Jacob Dresser, have taken unwearying pains to enlarge the scope of the Society, the result of which appears in an increased attendance upon the meetings, and in the greater number and variety of papers presented. The proceedings have been published annually through the past four years, and a compilation of the records of the first seventeen years of the Society's existence is now in progress with a view to publication.

THE BUILDINGS, NEW AND OLD.

The course of this report has involved frequent reference to the new structures which have been undertaken and completed during the year. The extension of the facilities of the Institute in this respect has, indeed, been remarkable, increasing the available floor-space occupied by the several departments and schools by at least 150 per cent. Even those members of the Corporation who have most attentively watched the work of the last ten years can hardly realize the relief that has been afforded thereby alike to the students and to the officers of instruction, the added pleasure and zest that have been given to the exercises in every department, or the opportunities allowed

for the enlargement and improvement of each and every part of the work done within the school. The Corporation, Faculty, and students alike are under a deep obligation to Mr. Philbrick, the Chairman of the Building Committee, and to Professor Wing, for the zeal, intelligence, and energy with which the great building under whose shadow we meet to-day has been pushed to completion, within a time which even the most sanguine deemed inadequate for so large and difficult a task.

The buildings, the property of the Corporation, used for the purposes of instruction, are five, of which, however, one will necessarily be torn down with the opening of the next season. These are (1) the Rogers Building, erected between 1864 and 1866, at a cost of about $300,000, which, with the exception of the low brick annex and the gymnasium, has, from the date of its completion to the present year, embraced all the services and departments of the school. This building is 92 x 145 ft. Its several stories contain about 53,000 sq. ft. of floor-space, exclusive of halls and entries, but inclusive of the rooms in the basement occupied for laboratory purposes.

In the re-assignment of space consequent upon the completion of the other buildings, the departments of Civil and Mechanical Engineering, of Applied Mechanics, of Geography and Geology, of Mineralogy and Lithology, of Physiology, Botany, and Biology, will remain in the Rogers Building. The suite of rooms in the second story will be occupied for the purpose of instruction in Mathematics. Until a new and more commodious Mining and Metallurgical laboratory can be provided on the land upon Garrison Street recently acquired by the Corporation, it will probably be unavoidable that this most interesting department of the Institute shall remain in the basement of the Rogers Building, where, already, some relief has been afforded it by the assignment of two large rooms recently vacated by the Chemical department. The Society of Arts will continue to hold its semi-monthly

meetings in this building, unless the increase in attendance should require a removal to the larger hall opening out upon Newbury Street, from the first floor of the new building.

(2) The Gymnasium and Drill Hall, erected in 1874 at a cost of about $8,600, at the corner of Boylston and Clarendon Streets, but removed in 1882 to Exeter Street, where it stands on land leased from the Boston & Albany Railroad Company. This building is 50 x 160 ft., one story high.

(3) The low brick annex, built in 1876, at a cost of about $7,000, primarily for the uses of the workshops, but occupied in part, also, by the Women's Laboratory, from the first, and by the department of Industrial Chemistry. This building is 40 x 170 ft., one story high. The workshops were at the opening of this school year removed to the new mechanical laboratories on Garrison Street, while the students of the Women's Laboratory were afforded in the new Kidder laboratories accommodations far superior to those previously enjoyed. The annex is at present occupied by the department of Industrial Chemistry. Inasmuch as the ground on which it stands is, since the completion of the new building, on the former site of the gymnasium, in excess of what the Institute is entitled by the concession of the State to occupy, it will be necessary to raze this building early in the coming year.

(4) The New Building of the Institute, on the corner of Boylston and Clarendon Streets, erected during the past season at a cost of about $165,000. This building is 90 x 156 ft., four stories and basement. In it the departments of Chemistry, of Physics, and of Architecture have been amply provided for. The Industrial Museum will occupy a hall 110 x 30 ft. on the second story. A suite of rooms in the third story have been allotted to recitations and lectures in Language, History, and Literature.

(5) The series of workshops, drawing and recitation-rooms, comprising about 25,000 square feet of available floor space, erected the past summer along the line of

the Providence Railroad at the foot of Garrison Street, for the accommodation of the workshops, of the School of Mechanic Arts, and of the Lowell School of Design.

THE ROGERS MEMORIAL FUND.

I cannot close this report without giving fresh expression to the gratification which every friend of the Institute feels in the establishment of the William Barton Rogers Memorial Fund of $250,000, through the exertions of two members of the Corporation, alike as a memorial to our illustrious first president, and as a guaranty and perpetual defence of the institution to which he devoted so many years of his honored life.

All of which is respectfully submitted,

FRANCIS A. WALKER,
President.

143

Mass. Institute of Technology.

President's Report,

Dec. 10, 1884.

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1884.

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VISITING COMMITTEES.

The School of Mechanic Arts, and the Lowell School of Industrial Design.

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M. DENMAN ROSS.

Departments of Literature, History, and Political Economy.

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Departments of Chemistry, Physics, and Biology.

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Departments of Mathematics and Civil Engineering.

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Departments of Mining and Metallurgy.

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To the Corporation of the

Massachusetts Institute of Technology.

The last school year — the twentieth in our series — has witnessed the full maintenance, and even an acceleration, of the remarkable rate of increase in the number of students attending the Institute of Technology, which has characterized the era of comparative prosperity which began in 1880.

The total number of persons registered in all the departments and schools under the control of the corporation, as by the catalogue, is 706, against an aggregate last year of 557.

Omitting from consideration the students of the Lowell Free School of Practical Design, the number this year is 645, against 497 last year. Still further excluding the students of the School of Mechanic Arts, we find the number of students in the School of Industrial Science to be 579, against 443 last year; making an increase of 136, or 31 per cent.

The following table exhibits the number of students in the School of Industrial Science each year, from the opening of the Institute to the present time: —

Year.	No. of Students.
1865–66	72
1866–67	137
1867–68	167
1868–69	172

Year.	No. of Students
1869–70	206
1870–71	224
1871–72	261
1872–73	348
1873–74	276
1874–75	248
1875–76	255
1876–77	215
1877–78	194
1878–79	188
1879–80	203
1880–81	253
1881–82	302
1882–83	368
1883–84	443
1884–85	579

STATISTICS OF EXAMINATIONS.

The results of the applications for admission to all classes of the School of Industrial Science thus far in the current school year, and of the examinations had thereupon, may be stated as follows: —

Forty-three were admitted without examination, either to the first year class upon presenting certificates of clear admission to some college of reputable standing, or upon the presentation of diplomas of graduation from some degree-conferring institution, classical or scientific, to the third year class, or to some department as special students; 134 were admitted upon examination, free of conditions; 47 were admitted upon examination, with one condition imposed; 29 were admitted with two conditions; 6 were admitted with three conditions; 36 applicants were rejected upon examination; 35 were admitted as special students, upon examination in the studies specially requisite to the partial courses which they proposed to follow.

The total number of applicants appears, therefore, to have been 330. Of those admitted upon examination, 26 have not thus far entered the school. In some instances, in the case of applicants heavily conditioned, this has been due to the advice of the Faculty, that a longer period be taken for preparation; in some, to a change of plans, to sickness, or other causes. The total number of applicants rejected or voluntarily withdrawing was thus 62.

These statistics are gratifying as showing a marked improvement in the preparation of candidates for admission. The number admitted free of conditions this year has been 134, as against 83 last year. The improvement noted is mainly due to a better understanding of the requirements for entrance to the Institute, and to greater care and pains taken by teachers in the preparatory schools, generally, to meet those requirements. The Institute of Technology now receives from many high schools and academies in New England a larger number of pupils than any other institution, and it has consequently become a matter both of self-interest and of pride on the part of the teachers of those schools to send up their students well-fitted for our examinations.

We have every reason to anticipate a still further progress in the same direction from year to year, as the teachers of the principal preparatory schools gain both in motive and in aptitude for fitting their pupils to meet our requirements. The chief improvement of the last two years, it goes almost without saying, has been in the better preparation given by high schools and academies in mathematical studies. Formerly it was not uncommon that, even in schools of reputation, this branch of instruction was intrusted to second-rate teachers, while all the honors were given to success in the study of the languages. Too often those who had charge of the instruction in mathematics were men who did not teach, but only heard lessons recited, which is a very different thing.

EXAMINATIONS AT DISTANT POINTS.

In addition to the entrance examinations in May and September, 1884, at Boston, examinations were held in May at Chicago, Cincinnati, St. Louis, San Francisco, and Washington, generally with the assistance of the superintendents of the city schools who have co-operated with the Faculty in the most cheerful and cordial spirit. It is believed that this course may, with mutual benefit, be continued in the future, and that the number of distant points at which an opportunity for local examinations shall be offered may well be increased the coming year. It is evident that the value of the results will not be measured by the number of applicants presenting themselves at these examinations in the first year or two, during which the system may be in operation.

STATISTICS OF RESIDENCE.

The gratifying tendency which was indicated in my last annual report, to a widening of the field from which our students are drawn, is even more noteworthy at the present time; the geographical extension of our constituency being quite as remarkable as the increase in the number of students.

Last year twenty-six States of the Union were represented on our lists of attendance. This year our students come from thirty-three States. Of the total number of 368 students in all classes of the regular courses, 235 are from Massachusetts, 41 from other New-England States, and 92 from outside New England. Of the total number of 579, including special students, 358 are from Massachusetts, 70 are from other New England States, and 151 from outside New England.

The following table shows the number of students of each specified class from each State or territory or foreign country: —

	Students of the Regular Courses.					Special Students.	Aggregate School of Industrial Science, 1884-5.	Aggregate School of Industrial Science, 1883-4.
	Fourth Year.	Third Year.	Second Year.	First Year.	Total Students of the Reg. Courses.			
Massachusetts	23	36	53	123	235	123	358	288
Maine	1	1	5	4	11	8	19	19
New Hampshire	..	1	5	5	11	6	17	17
Connecticut	..	1	2	5	8	10	18	11
Vermont	..	2	..	1	3	1	4	6
Rhode Island	1	1	..	6	8	4	12	4
New York	1	2	1	7	11	5	16	15
Pennsylvania	1	1	2	6	10	6	16	8
New Jersey	..	..	..	2	2	2	4	2
Ohio	..	3	1	8	12	8	20	9
Illinois	1	3	3	5	12	9	21	14
Indiana	..	1	..	..	1	3	4	2
Wisconsin	..	..	..	..	..	1	1	1
Michigan	..	..	..	1	1	..	1	..
Iowa	..	1	2	..	3	2	5	4
Minnesota	.	..	1	1	2	4	6	5
Kansas	..	1	1	..	2	..	2	2
Nebraska	..	..	..	1	1	..	1	..
Colorado	..	..	..	..	..	1	1	..
Nevada	..	..	1	..	1	..	1	1
California	..	..	..	2	2	1	3	1
Oregon	..	..	..	1	1	..	1	..
Montana	..	..	..	..	..	..	..	1
Delaware	..	..	..	1	1	1	2	1
Maryland	..	2	..	3	5	3	8	9
Dist. of Columbia	..	..	..	2	2	3	5	3
Virginia	..	..	1	1	2	..	2	3
North Carolina	1	1	..	..	2	..	2	3
South Carolina	..	..	..	..	..	1	1	1
Georgia	..	..	1	1	2	1	3	1
Alabama	..	..	1	..	1	1	2	..
Kentucky	1	1	..	2	4	1	5	2
Tennessee	..	..	..	2	2	1	3	..
Missouri	..	..	..	..	..	2	2	2
Texas	..	..	..	..	..	1	1	..
Prov. of Quebec	..	..	2	..	2	..	2	2
" Ontario	..	1	..	1	2	..	2	..
New Brunswick	..	..	1	..	1	2	3	3
Nova Scotia	..	..	1	..	1	..	1	..
Scotland	..	1	1	..	2	..	2	1
Cuba	..	..	..	1	1	..	1	..
Japan	..	..	..	1	1	..	1	..
South America	..	..	..	..	..	..	..	1
India	..	..	..	..	..	..	..	1
	30	60	85	193	368	211	579	443

Among the gratifying features of this table is the appearance of students from not less than eleven Southern States, to an aggregate of 33, against eight States, with an aggregate of 22 students, last year.

Believing, as I do, in the almost boundless possibilities of industrial growth in that portion of our country, it is with keen delight that I see so many of the generous youth of the South turning from the rhetorical and dialectical exercises which so engrossed the educational interest of the generations past, to qualify themselves, by scientific and technological study and practice, to lead and direct the development of the industrial energies and the natural resources of that fair land. I rejoice to add, that, in manliness of character, sobriety of conduct, and strictness of attention to the prime object of their residence here, these young gentlemen do honor to the States from which they come.

PROPORTION OF OLD AND OF NEW STUDENTS.

The table following exhibits, for each year of the school's history, the distribution of the total number of students among two classes: first, those students remaining whose names are found upon the catalogue of the year preceding that for which the statement is given; and secondly, those students whose names appear as new names upon the catalogue of the year to which the statement relates.

It will appear from this table, that the rapid increase noted last year in the number of students remaining over from year to year still continues; the number for 1879 having been 102; for 1880, 121; for 1881, 136; for 1882, 173; for 1883, 231; while that for 1884 is 311.

Year.	(1) Total No. of Students.	(2) No. of Students in the Catalogue of the previous year who remain in the Institute.	(3) No. of New Students entering before issue of Catalogue.	(4) Of those in column (3) the following number were regular first year Students.	(5) No. of New Students not of the regular first year class.
1866-67	137	34	103	58	45
1867-68	167	79	88	54	34
1868-69	172	82	90	50	40
1869-70	206	90	116	63	53
1870-71	224	109	115	71	44
1871-72	261	122	139	82	57
1872-73	348	173	175	112	63
1873-74	276	171	105	59	46
1874-75	248	159	89	35	54
1875-76	255	139	116	65	51
1876-77	215	130	85	31	54
1877-78	194	96	98	47	51
1878-79	188	99	89	34	55
1879-80	203	102	101	34	67
1880-81	253	121	132	62	70
1881-82	302	136	166	86	80
1882-83	368	173	195	114	81
1883-84	443	231	212	140	72
1884-85	579	311	268	186*	82

PROPORTION OF REGULAR AND OF SPECIAL STUDENTS.

Still another table which has been prepared exhibits both the absolute number of regular and of special students, as by the catalogue of each successive year, and also the proportion existing between these two classes.

It will be seen that the proportion of regular students has, since 1881, risen from 54 to 64 per cent, — a highly gratifying result; while still further progress in this direction is reasonably to be anticipated as the effect of causes manifestly operating in the school. At the same time the Faculty will not cease to encourage the coming to the Institute of certain classes of special students whose means or family circumstances or whose age at the time of entrance will not permit them to take the full regular four years' course. Among such special students have always

* In addition, seven students are repeating the first year.

been found some of our best scholars ; and from them have come some of our most successful engineers, chemists, and architects.

Year.	No. of Regular Students.	No. of Special Students.	Total No. of Students.	Percentage.	
				Regular.	Special.
				Per cent.	Per cent.
1865-66	64	8	72	89	11
1866-67	110	27	137	80	20
1867-68	124	43	167	74	26
1868-69	105	67	172	61	39
1869-70	125	81	206	71	29
1870-71	143	81	224	64	36
1871-72	180	81	261	69	31
1872-73	235	113	348	68	32
1873-74	182	94	276	66	34
1874-75	170	78	248	69	31
1875-76	182	73	255	71	29
1876-77	134	81	215	62	38
1877-78	117	77	194	60	40
1878-79	103	85	188	55	45
1879-80	110	93	203	54	46
1880-81	140	113	253	55	45
1881-82	164	138	302	54	46
1882-83	219	149	368	60	40
1883-84	272	171	443	61	39
1884-85	368	211	579	64	36

COURSES OF INSTRUCTION.

I repeat my remark of last year, that the fortunes of the Institute, the changing conditions of the national industry, the varying tastes and predilections of individuals, and, to a certain extent, the tendency of students to move together combine to produce not a little fluctuation in the numbers of students within the several courses and departments. The following table exhibits the number of persons who have graduated within each of the several courses at each successive year since the first diplomas were conferred in 1868 : —

Year.	I. Civil Engineering.	II. Mechanical Engineering.	III. Mining Engineering.	IV. Architecture.	V. Chemistry.	VI. Metallurgy.	VII. Natural History.	VIII. Physics.	IX. General Course.	Total.
1868	6	1	6	..	..	..	..	..	1	14
1869	2	2	..	..	1	..	..	..	.	5
1870	4	2	2	..	1	..	..	..	1	10
1871	8	2	5	..	2	..	..	..	..	17
1872	3	1	5	..	3	..	..	..	..	12
1873	12	1	3	1	7	..	..	..	1	25
1874	10	4	1	1	..	..	..	..	2	18
1875	10	7	6	1	1	..	..	1	2	28
1876	12	8	7	.	5	1	2	3	3	41
1877	12	6	8	4	2	..	..	..	..	32
1878	8	2	2	3	3	..	..	..	1	19
1879	6	8	3	1	3	..	1	1	..	23
1880	3	..	3	..	1	..	..	.	1	8
1881	3	5	6	3	8	..	1	..	2	28
1882	2	5	5	3	6	..	1	1	1	24
1883	3	7	4	1	3	..	..	..	..	18
1884	5	6	13	..	12	..	..	..	..	36
Total,	109	67	79	18	58	1	5	6	15	358

In the following table appears the distribution of the 175 regular students of the three upper classes, among the several courses. In one instance the significance of the numbers given to the courses will be seen to be changed from what it is in the table just preceding; viz., in this, that Course VI. is no longer Metallurgy, but is now Electrical Engineering.

Year.	I. Civil Engineering.	II. Mechanical Engineering.	III. Mining Engineering and Metallurgy.	IV. Architecture.	V. Chemistry.	VI. Electrical Engineering.	VII. Natural History.	VIII. Physics.	IX. General Course.	Total.
4th year class,	7	7	8	2	4	1	..	..	1	30
3d year class,	9	20	8	2	6	15	..	..	..	60
2d year class,	13	27	12	5	10	14	1	1	2	85
Total . .	29	54	28	9	20	30	1	1	3	175

THE WORK OF SPECIAL STUDENTS.

The 211 special students in the School of Industrial Science cannot be classified systematically; but the following table exhibits the number of special students pursuing each particular branch of study, according to the attendance papers filed by them and approved by the Faculty:—

NUMBER OF SPECIAL STUDENTS ATTENDING EXERCISES IN THE FOLLOWING DEPARTMENTS OF STUDY OR PRACTICE.

Architecture	42	German	84
Biology	23	Mathematics	109
Chemistry	83	Mechanical Engineering	55
Civil Engineering	20	Military Drill	28
Drawing	43	Mining and Metallurgy	11
Descriptive Geometry	37	Physics	89
English	78	Shop Work	56
French	26	Zoölogy	6
Geology	17		

Total number of entries, by special students	807
Total number of special students	211
Average number of entries	3.8

CORRESPONDING NUMBERS FOR 1883–84.

Total number of entries, by special students	596
Total number of special students	171
Average number of entries	3.5

It may be of interest to note the numbers of students, either regular or special, pursuing certain leading branches of study, in each of the four years, which are as follows:—

	First Year.	Second Year.	Third Year.	Fourth Year.	Total.
Mathematics	225	137	72	..	434
Chemistry	243	35	21	15	314
English	212	106	77	..	395
French	205	..	..	..	205
Physics	..	148	91	5	244
German	..	126	89	2	217
Shopwork*	..	78	32	14	124

* Exclusive, of course, of the students of the School of Mechanic Arts. The corresponding number last year was 95.

THE CORPS OF INSTRUCTORS.

An increase in the instructing staff of the Institute has of course been required, to meet the demands of the large incoming classes. The number of instructors of all grades, excluding those persons who are announced as lecturers for the year, is 57, against 48 last year. The number of professors is 14; of associate professors, 3; of assistant professors, 11; of instructors, 15; and of assistants, 14.

The following table shows the number of teachers of each recognized grade, in each year since the foundation of the school.

Year.	Professors.	Associate Professors.	Assistant Professors.	Instructors.	Assistants.	Total.
1865-66	10	..	..	..	..	10
1866-67	12	..	..	2	..	14
1867-68	12	..	1	2	2	17
1868-69	13	..	..	6	1	20
1869-70	16	..	1	6	2	25
1870-71	18	..	2	7	5	32
1871-72	21	..	2	11	1	35
1872-73	23	..	2	9	1	35
1873-74	20	..	3	10	4	37
1874-75	20	..	3	7	3	33
1875-76	23	..	..	6	8	37
1876-77	21	..	..	4	10	35
1877-78	20	..	..	3	14	37
1878-79	18	..	..	7	12	37
1879-80	16	..	..	7	8	31
1880-81	15	..	2	6	7	30
1881-82	17	..	3	6	11	37
1883-83	16	..	3	10	11	40
1883-84	15	..	8	15	10	48
1884-85	14	3	11	15	14	57

The changes among the professors and associate and assistant professors, during the year, have been mainly in the way of additions to the existing staff. In one instance only has the change been in the nature of loss. Professor John M. Ordway, after a continuous service of fifteen years, has left the chair of Industrial Chemistry and Metallurgy,

to accept the charge of a more extensive department in the new Tulane University of New Orleans. Professor Ordway's unremitting labors and unflagging zeal have identified him in a peculiar degree with the Institute of Technology.

In view of Professor Ordway's retirement, it was not deemed desirable to appoint any person to undertake the double charge which had rested upon him. The instruction in Metallurgy has devolved upon Professor Richards and Mr. F. W. Clarke, assisted by Mr. Henry M. Howe as lecturer for the current year; while the other portion of Professor Ordway's work has devolved upon Dr. Norton, who has been appointed assistant professor of Organic and Industrial Chemistry. The instructing staff in the chemical department has been further strengthened by the appointment of Mr. Thomas E. Pope, late professor in the Iowa Agricultural College, a former student of the Institute, as assistant professor of Analytical Chemistry.

Mr. Linus Faunce, a graduate of the Institute in the class of 1877, and subsequently engaged in the engineering department of the New York & New England Railroad, has been appointed assistant professor of Drawing, and placed in charge of the drawing of the first year, and of the instruction in Descriptive Geometry.

Mr. Alfred E. Burton, a graduate of Bowdoin College, subsequently employed upon the United States Coast Survey, has been appointed assistant professor of Topographical Engineering.

In the department of Mechanical Engineering, three of the instructors of last year have been promoted to the grade of assistant professors, as follows: Mr. Peter Schwamb, in Mechanism; Mr. Charles H. Fisher, in Mechanical Engineering; Mr. Cecil H. Peabody, in Applied Mechanics. Mr. Schwamb has, also, in accordance with the recommendation of the Faculty, been announced as Director of the School of Mechanic Arts. Professor Schwamb has conducted the various services of the school, thus far in the school year, with intelligence and sound judgment.

THE SUBSIDIARY SCHOOLS.

The School of Mechanic Arts and the Lowell School of Practical Design have done their work efficiently during the past year. The number of students in the former school is purposely restricted; the number of students in the latter school shows some increase: but no large accessions are to be anticipated until it shall be within the means of the Corporation to provide a separate building for this school on the new land. The attention of the Corporation has recently been called to the desirability of such action in the near future, through a report of the visiting committee, Mr. Atkinson, chairman.

LABORATORIES AND RECITATION ROOMS.

After the enormous extensions of the year 1882–83, the changes in laboratories and recitation rooms made during the past year seem slight; yet, without such a comparison, they would be seen to constitute a very important addition to the accommodations and facilities at the disposal of the Institute.

The great increase in the number of students in Mechanical Engineering has required that the story of the Rogers Building, heretofore shared by the Civil and Mechanical Engineering departments, should be surrendered to the latter almost entire, one room being reserved for the temporary use of the School of Mechanic Arts, and another for blowpipe analysis. All the rooms, halls, etc., on this floor, upon the Newbury-street side of the building, have been thrown into one great drawing-room, of the size of Huntington Hall, which has been provided with 130 drawing-tables.

The Civil Engineering department, thus crowded out of the Rogers Building, has found temporary, but most agreeable and commodious, offices and drawing-rooms on the east side of the second story of the new building, where it

is anticipated this department will remain until provided for, more amply and more favorably still, through an extension of the "lantern story" of the Rogers Building, incidental to a removal of the present unsatisfactory and unsightly roof.

In the basement of the new building a photometric room has been parted off in the main eastern hall for the use of the department of Physics. In the large room at the Newbury-street end of the building, a room 30 x 20 feet has been set apart as a laboratory for the Architectural department, where experiments can be made with limes, mortars, and cements, and problems be worked out in the actual materials of construction.

The western third of this large hall has been partitioned off as a storeroom (40 x 30 feet), for the supplies and apparatus of the Chemical department; while the former supply and apparatus room has been fitted up in the best manner for the department of Industrial Chemistry.

Still another addition has been made to the ample chemical laboratories of the Institute, through fitting up room No. 34 on the third floor of the new building as a laboratory of Sanitary Chemistry, instruction in this subject having been introduced as an option in the third and fourth years of the chemical course.

This laboratory will relieve the analytical laboratory in certain lines of work, and will also afford facilities for special students who desire to learn the methods of analyzing air and water, of detecting adulteration in milk, bread, and other articles of food, of testing illuminating oils, and of making special chemical investigations in matters relating to public health. The laboratory has been attached to the department of Professor Nichols, whose investigations in these lines are too well known to require an allusion here. Mrs. Ellen H. Richards has been appointed instructor in Sanitary Chemistry.

The most important, however, of all changes, since the

last annual report, in the buildings of the Institute, has been that effected in the Rogers Building, by which the entire rear half of the basement, including the former third and fourth year chemical laboratories, has been remodeled and renovated, so as to answer the purposes of the department of Mining and Metallurgy in a degree which, a year ago, would hardly have been deemed possible by any member of the Corporation or of the Faculty.

It has long been almost a foregone conclusion that, in the course of time, the mining and metallurgical laboratories would be removed to some other spot, perhaps to the new land at the foot of Garrison Street. A careful survey of the basement of the Rogers Building, however, during the past year, satisfied the executive committee, that, with some structural changes, the space there available could be so utilized as to meet the present and prospective wants of this department. In consequence, the front and the rear half of the basement having been separated by a fire-proof wall, the large staircase from the first story to the basement was removed, thus preventing the upward escape of laboratory fumes, while affording space for ample lavatory, toilet, and supply rooms; partitions and platforms no longer required were thrown down; new arrangements for ventilation and for the introduction of water and steam were effected; a system of storage-vaults was constructed underground, outside the main wall of the building upon the eastern side; the chimney-flues were lined far up with fire-brick; all the furnaces were rebuilt from the floor upwards; all the old machinery was taken out, and thoroughly overhauled and repaired, so far as it could be made to answer the purpose satisfactorily; while new machines, to at least an equal extent, were introduced.

As the result of these alterations and additions, which were effected at a cost of between six thousand and seven thousand dollars, the accommodation for students in the mining and metallurgical laboratories has been increased

nearly threefold, while the quality of the work that may be done has been, if not proportionately, at least very greatly improved. The storage-vaults will allow the ore of many mines to be kept in stock; while the building, viewed as a fire-risk, has actually been improved by the changes recited. These laboratories now stand, in their scope, capacity, and equipment, unrivalled and unapproached. In the assaying-room, twenty students can work at once with fire; while the furnace-room contains furnaces sufficient in number and size, to enable almost any variety of ores to be treated economically, in quantities from twenty-five to a thousand pounds. A water-jacket furnace, having the capacity to smelt a ton of lead or copper-ore in a day, has been presented by a friend of the Institute since the term began, and is now in place. The laboratory for crushing and separating machinery contains four full suites, with a great variety of special and novel apparatus.

The past year has seen the demolition of the low brick annex on the main square of the Institute, which was erected eight years ago, to serve the purposes of the woman's laboratory and of the mechanic art shops. By the erection of the building at the corner of Clarendon street the space occupied by the annex had become in excess of that which the Institute might, under the grant of the State, lawfully cover with structures of any kind; and it had, moreover, become painfully unsuitable and inadequate to the increasing needs of the school.

In removing this from the face of Institute square, however, we must not be ungrateful for the good service it rendered in the earlier days of poverty, doubt, and difficulty, nor forget by what labors and sacrifices even this now discarded shelter was purchased for two of the infant departments of the school.

This account of the development of the Institute, and the multiplication and extension of its services and offices,

would not be complete without the statement that the growing appreciation of technological education throughout the community, and the fast-increasing resort of students to our halls, make the more imperative the need that has been so long and so painfully felt, for the ample, liberal endowment, in perpetuity, of this school of industrial science, with revenue-bearing funds.

Down to this time, the munificence of the friends of the Institute has mainly been directed towards rearing these costly buildings, and equipping them with the best appliances of scientific investigation and practice, and towards meeting the current charges of maintaining our varied services through the period of outlay and experiment. The future has not yet been provided for. The establishment of the William Barton Rogers Memorial Fund, in 1883, formed alike a worthy monument to the illustrious founder of the Institute, and a notable and noble addition to its permanent resources. But the need of early and large endowments, above all that have heretofore been so generously contributed, is urgent and imperative. Shall funds be wanting to place this school, whose unsurpassed usefulness among the educational institutions of the country stands acknowledged by the unprecedented accession of students from every part of the land, upon an assured basis, and to give it the means fully to meet the growing demands of the community?

Large additional endowments are needed,

1. As a reserve against hard times, against the occurrence of financial disaster, and even against the possibilities of temporary internal mismanagement. It is a perilous position for an educational institution that it should depend so largely upon tuition fees as to draw one-half of its revenue from this source. Yet five-sixths of the income of the Institute of Technology will be thus derived the current year.

2. As a basis for free scholarships for a large number of deserving students, whose means would be severely taxed

to meet the expenses of their maintenance, even were the charges of their tuition remitted. With an aggregate attendance of nearly six hundred in the School of Industrial Science, we ought to have at least sixty free scholarships, whereas but five have thus far been provided.

3. As a means to reducing somewhat the very high tuition fees now necessarily exacted from all students.

4. To place it in the power of the corporation to raise the compensation of the professors and other instructors of the school, to correspond, if not with the incomes of successful practitioners in the several scientific professions, at least with the salaries of professors and instructors in the leading classical colleges.

5. To enable the corporation and faculty, through the long future of the school, to meet promptly and fully all the progressive demands of industrial education, as well as, through original research and investigation, to pay back each year some part of that great debt which the arts owe to science.

All of which is respectfully submitted.

FRANCIS A. WALKER, *President.*

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Mass. Institute of Technology.

President's Report,

Dec. 9, 1885.

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1885.

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To the Corporation of the Massachusetts Institute of Technology.

DURING the twelve months which have passed since I presented my last annual report, the school year 1884–85 has come to a successful termination, and the school year 1885–86 has auspiciously begun.

It was not my privilege to attend the closing exercises of the year past; since, for the sake of much-needed rest, and with the consent of the Executive Committee, I had sailed for Europe three weeks previous to the graduating ceremonies. Professor Runkle was chosen by the Faculty to represent them on that occasion. Of the 30 students of the fourth year, who were candidates for the degree of Bachelor of Science, 27 were admitted to that degree.

The results of the annual examinations to determine the fitness of the students of the first, second, and third years, severally, to pass into higher classes, were on the whole very gratifying, showing, in comparison with the results of previous years, a steady rise in the degree of success attending the instruction in the Institute. I think it may fairly be said, that, while the present school opens with a larger number of students in each of the second, third, and fourth year classes than ever before in our history, it also opens with a higher average scholarship in each of those classes than was ever previously attained. This is due in part to the steady improvement, of late years, in the preparation for the work of the Institute afforded by the "fitting schools;" and, in even larger measure, to the enlargement of the means of instruction here, including both a considerable increase in the numbers of the teaching-staff and a very great extension of the room, of the apparatus, and of the mechanical facilities generally, available for recitation, drawing, shop, and laboratory work.

The total number of persons registered in all the departments and schools under the control of the Corporation is 730; against an aggregate, last year, of 706.

Omitting from consideration the students of the Lowell Free School of Practical Design, the number this year is 669, against 645 last year. Still further excluding the number of students in the School of Mechanic Arts, we find the number of students in the School of Industrial Science to be 609, against 579 last year; making the increase here 30, or 5 per cent.

The following table exhibits the number of students in the School of Industrial Science, each year, from the opening the Institute to the present time: —

Year.	No. of Students.
1865–66	72
1866–67	137
1867–68	167
1868–69	172
1869–70	206
1870–71	224
1871–72	261
1872–73	348
1873–74	276
1874–75	248
1875–76	255
1876–77	215
1877–78	194
1878–79	188
1879–80	203
1880–81	253
1881–82	302
1882–83	368
1883–84	443
1884–85	579
1885–86	609

This aggregate is divided among the several classes as follows:—

Regular students,	Fourth year . . .	53
" "	Third " . .	63
" "	Second " . . .	112
" "	First " . .	187
Special students .	. . . . .	194
		609

If we should attempt further to distribute the body of special students according to the predominant studies pursued by them, we should reach the following approximate statement of the division of the whole number of students among the several years of the course:—

	Regular.	Special.	Total.
Fourth year	53	24	77
Third "	63	52	115
Second "	112	81	193
First "	187	37	224
	415	194	609

STATISTICS OF EXAMINATIONS.

The results of the applications for admission to all classes of the school of Industrial Science thus far in the current school year, and of the examinations had thereupon, may be stated as follows:—

Forty-nine were admitted without examination, either to the first year class upon presenting certificates of clear admission to some college of reputable standing, or, upon the presentation of diplomas of graduation from some degree-conferring institution, classical or scientific, to the third year class, or to some department as special students;

145 were admitted upon examination, free of conditions; 37 were admitted with one condition imposed; 26 were admitted with two conditions; 8 were admitted with three conditions; 36 applicants were rejected upon examination; 7 were admitted as special students, upon examination in the studies specially requisite to the partial courses which they proposed to follow.

The total number of applicants appears, therefore, to have been 308. Of those admitted upon examination, 39 have not thus far entered the school. In some instances, in the case of applicants heavily conditioned, this has been due to the advice of the Faculty, that a longer period be taken for preparation; in some, to a change of plans, to sickness, or other causes. The total number of applicants rejected or voluntarily withdrawing was thus 75.

The foregoing figures, in comparison with those of previous years, show a progressive improvement in the preparation of candidates for admission. Of the total number submitting to examination, the proportion of those who were admitted free of conditions was 56 per cent this year, as against 47 per cent last year, and only 33 per cent in 1883. This result is explained by the comment made, in my last annual report, upon the statistics of examination there presented; viz., that the improvement noted is mainly due to a better understanding of the requirements for entrance to the Institute, and to greater care and pains taken by teachers in the preparatory schools, generally, to meet those requirements.

EXAMINATIONS AT DISTANT POINTS.

In addition to the entrance examinations held in Boston in June and September, 1885, examinations were also conducted in June at Atlanta, Chicago, Cincinnati, Denver, Nashville, New Orleans, New York, Philadelphia, San Francisco, St. Louis, St. Paul, and Washington, generally with the assistance of the superintendents of the city schools, who co-operated with the Faculty in the most cordial manner.

STATISTICS OF RESIDENCE.

As was the case last year, thirty-three States of the Union, besides the District of Columbia, are represented on our lists of students. Canada, Scotland, Chili, Cuba, and Japan have also sent us students.

Of the total number of 415 students, in all the regular courses, 284 are from Massachusetts, 48 from other New-England States, and 83 from outside New England. Of the total number of 609, including special students, 387 are from Massachusetts, 78 are from other New-England States, and 144 from outside New England.

The following table shows the number of students of each specified class, from each State or foreign country.

State.	Fourth Year.	Third Year.	Second Year.	First Year.	Total Reg.	Special.	Total.
Alabama	..	..	..	..	..	2	2
California	..	..	2	2	4	1	5
Colorado	..	..	..	1	1	..	1
Connecticut	2	1	2	2	7	9	16
Delaware	..	..	1	..	1	..	1
Dist. of Columbia,	..	..	1	..	1	3	4
Georgia	..	1	..	..	1	1	2
Illinois	4	1	2	6	13	7	20
Indiana	1	..	..	..	1	..	1
Iowa	..	3	..	1	4	2	6
Kansas	1	1	..	..	2	..	2
Kentucky	1	..	..	1	2	3	5
Louisiana	..	..	..	1	1	..	1
Maine	2	4	2	6	14	8	22
Maryland	..	..	1	..	1	..	1
Massachusetts	35	40	77	132	284	103	387
Michigan	..	..	1	2	3	..	3
Minnesota	..	..	1	1	2	3	5
Mississippi	..	..	..	..	..	1	1
Missouri	..	..	..	1	1	1	2
Nebraska	1	..	..	1	2	1	3
Nevada	..	..	..	..	..	1	1
New Hampshire	..	5	3	6	14	8	22
New Jersey	..	..	2	..	2	3	5
New York	1	2	3	5	11	6	17
North Carolina	1	..	..	..	1	..	1
Ohio	..	1	3	2	6	12	18
Oregon	..	..	1	..	1	..	1
Pennsylvania	1	..	2	6	9	6	15
Rhode Island	..	..	3	6	9	3	12
South Carolina	..	..	1	1	2	..	2
Tennessee	..	..	..	..	..	2	2
Vermont	2	..	1	1	4	2	6
Virginia	..	1	1	2	4	1	5
Wisconsin	..	..	..	..	..	1	1
	52	60	110	186	408	190	598
Foreign Country.							
Chili	..	..	1	..	1	..	1
Cuba	..	..	..	..	..	1	1
Japan	..	..	1	..	1	..	1
New Brunswick	..	1	..	..	1	2	3
Prov. of Quebec	..	2	..	1	3	..	3
Scotland	1	..	..	..	1	1	2
	53	63	112	187	415	194	609

It will here be observed that the number of scholars, in all the classes, who have Massachusetts for their residence, is 387, being 63.5 per cent of the total number of students.

I have thought that an analysis of this large aggregate, to ascertain the numbers coming to us from the several counties and towns of the Commonwealth, might be interesting and instructive.

I find that of the 14 counties of Massachusetts, Dukes and Nantucket alone fail to appear. In the 12 counties represented, 94 cities and towns maintain students at the Institute. The first column of the following table shows the number of cities and towns in each county sending pupils; the second column, the aggregate number of pupils from each county. It appears that Suffolk, our own county, furnishes us 120 pupils; Middlesex County comes next, with 108; Essex, third, with 53; Norfolk, fourth, with 38; no one of the remaining counties sending so many as 20.

County.	No. of Towns.	No. of Students	County.	No. of Towns.	No. of Students
Barnstable . . .	5	5	Middlesex . . .	26	108
Berkshire . . .	2	5	Norfolk	12	38
Bristol	5	16	Plymouth . . .	10	18
Essex.	16	53	Suffolk	3	120
Franklin. . . .	1	2	Worcester . . .	11	14
Hampden . . .	2	7			
Hampshire . . .	1	1		94	387

The following is a list of the towns, 26 in number, which send four or more scholars to the Institute: —

Boston 115	Plymouth . . . 6	Beverly 4
Newton 27	Springfield . . . 6	Canton 4
Brookline . . . 14	Fall River . . . 5	Chelsea 4
Cambridge . . . 12	Hyde Park. . . 5	Haverhill . . . 4
Lawrence . . . 10	Malden 5	Melrose. . . . 4
Somerville . . . 10	Newburyport . . 5	Pittsfield . . . 4
Lowell 9	Stoughton . . . 5	Salem 4
Lynn. 9	Andover . . . 4	Winchester . . 4
New Bedford . . 7	Arlington . . . 4	

PROPORTION OF OLD AND OF NEW STUDENTS.

The table following exhibits, for each year of the school's history, the distribution of the total number of students among two classes: first, those students remaining whose names are found upon the catalogue of the year preceding that for which the statement is given; and, secondly, those students whose names appear as new names upon the catalogue of the year to which the statement relates: —

Year.	(1) Total No. of Students.	(2) No. of Students in the Catalogue of the previous year who remain in the Institute.	(3) No. of New Students entering before issue of Catalogue.	(4) Of those in column (3) the following number were regular first year Students.	(5) No. of New Students not of the regular first year class.
1866–67	137	34	103	58	45
1867–68	167	79	88	54	34
1868–69	172	82	90	50	40
1869–70	206	90	116	63	53
1870–71	224	109	115	71	44
1871–72	261	122	139	82	57
1872–73	348	173	175	112	63
1873–74	276	171	105	59	46
1874–75	248	159	89	35	54
1875–76	255	139	116	65	51
1876–77	215	130	85	31	54
1877–78	194	96*	98	47	51
1878–79	188	99	89	34	55
1879–80	203	102	101	34	67
1880–81	253	121	132	62	70
1881–82	302	136	166	86	80
1882–83	368	173	195	114	81
1883–84	443	231	212	140	72
1884–85	579	311	268	186	82
1885–86	609	369	240	177*	63

It appears from the foregoing, that the number of students remaining over has been increased by 58, while the number of students registered for the first time is smaller by 28; making the net gain in the School of Industrial Science, 30, as previously stated.

Of the 369 students remaining over from a previous registration, one was at the beginning of last year registered as a regular student of the fourth year; 52 were registered as regular students of the third year (the regular students of the present fourth year class now number 53); 73 were registered as regular students of the second year (the regular students of the present third year class now number 63); and 148 were registered as regular students of the first year (the students of the present second year class now number 112); while 95, out of this number, were registered at the beginning of last year as special students.

* In addition, 10 students are repeating the first year.

AGES OF STUDENTS ON ENTRANCE.

Another class of facts which I have deemed it desirable to present relates to the ages of our students upon entrance. I have, therefore, caused the statistics of this subject to be compiled with reference to the regular students of the incoming first year class. The class numbers 187. From these we should except two cases of students of unusual age; viz., one of 23 and one of 24 years. Three cases also fall out, because the ages are not stated. These deductions leave 182 as the number of students whose ages have been made the subject of computation.

The results appear in the following table: —

Age.		No. of Students within each period.	Aggregate No. of Students by 6-mo's groups.	Age.		No. of Students within each period.	Aggregate No. of Students by 6-mo's groups.
Year of Life completed.	Additional Months.			Year of Life completed.	Additional Months.		
16	..	2	..	18	6	7	..
16	1	1	..	18	7	4	..
16	2	2	..	18	8	3	..
16	3	2	..	18	9	5	..
16	4	1	..	18	10	3	..
16	5	3	11	18	11	1	23
16	6	2	..	19	..	6	..
16	7	4	..	19	1	3	..
16	9	6	..	19	2	3	..
16	10	2	..	19	3	2	..
16	11	2	16	19	4	5	..
17	..	6	..	19	5	2	21
17	1	4	..	19	6	1	..
17	2	5	..	19	7	3	..
17	3	6	..	19	8	4	..
17	4	3	24	19	10	2	..
17	6	3	..	19	11	1	11
17	7	4	..	20	..	1	..
17	8	4	..	20	2	3	..
17	9	5	..	20	3	1	..
17	10	2	..	20	5	1	6
17	11	2	20	20	7	2	..
18	..	8	..	20	8	1	3
18	1	11	..	21	1	1	..
18	2	1	..	21	4	1	2
18	3	6	..	21	6	2	..
18	4	8	..	21	10	1	3
18	5	8	42	..	..	..	..

From the foregoing table it appears that the average age of the 182 students taken for this comparison is 218.53 months, or 18 years, 2 months, and 16 days. It appears that precisely one-half (91) of the students taken are of the age of 18 years and 2 months, or under.

It appears that 27 students are between 16 and 17 years of age, and 14 are above 20; leaving 141 between 17 and 20, of whom 44 are between 17 and 18, 65 between 18 and 19, 32 between 19 and 20.

A fact which gives especial importance to these figures is found in the rule this year adopted, and entered for the first time in the catalogue laid before you to-day, — that after September, 1886, no student will be received into the School of Industrial Science who has not attained the age of 17 years. The Faculty believe that not only will the adoption of this rule have a wholesome effect in holding back from entrance into the school scholars who are of too tender and immature an age to take the studies and exercises of the Institute to the best advantage, but that this regulation, as promulgated in the catalogue, will have a certain influence in inducing students and their parents to protract the period of their preparatory studies even beyond the mimimum limit thus fixed.

The average age, on entrance, of the class graduating last May, and of the three upper classes at present in the school, is found, when computed on the same basis as the above, (i.e., omitting all students over 22 years of age), to be as follows: —

Class of	Av. Age in Months.	Class of	Av. Age in Months.
1885	220.50	1888	220.66
1886	218.45	1889 (as above)	218.53
1887	218.88		

PROPORTION OF REGULAR AND OF SPECIAL STUDENTS.

Another table which has been prepared exhibits both the absolute number of regular and of special students, as by the catalogue of each successive year, and also the proportion existing between these two classes: —

Year.	No. of Regular Students.	No. of Special Students.	Total No. of Students.	PERCENTAGE.	
				Regular.	Special.
				Per cent.	Per cent.
1865-66	64	8	72	89	11
1866-67	110	27	137	80	20
1867-68	124	43	167	74	26
1868-69	105	67	172	61	39
1869-70	125	81	206	71	29
1870-71	143	81	224	64	36
1871-72	180	81	261	69	31
1872-73	235	113	348	68	32
1873-74	182	94	276	66	34
1874-75	170	78	248	69	31
1875-76	182	73	255	71	29
1876-77	134	81	215	62	38
1877-78	117	77	194	60	40
1878-79	103	85	188	55	45
1879-80	110	93	203	54	46
1880-81	140	113	253	55	45
1881-82	164	138	302	54	46
1882-83	219	149	368	60	40
1883-84	272	171	443	61	39
1884-85	368	211	579	64	36
1885-86	415	194	609	68	32

It will be seen that the proportion of regular students rose from 54 per cent in 1881, to 60 per cent in 1882, to 61 per cent in 1883, to 64 per cent in 1884; while this year it reaches 68 per cent, the actual number of regular students being greater by 47 than last year.

Of the 194 special students, 31 are students taking the two years' partial course in architecture.

The steady increase in the proportion of regular students, recorded above, is gratifying; but this remark needs to be accompanied by the statement, in the nature of a disclaimer, that a certain and not inconsiderable porportion of "specials" will always constitute a desirable element in our body of students.

The system relating to special students performs, in this institution, a somewhat unusual function, which is esteemed of great importance. First, in that, in this way, we are enabled to receive and provide for the wants of many per-

sons whose means or family circumstances, or whose age at the time of entrance, will not permit them to take a regular course. Among such special students have always been found some of our best scholars; and from this class have gone out many eminently successful engineers, architects, and chemists.

Secondly, in that, in this way, we are able to do what is best to be done in the case of that comparatively small class of young persons whose intellectual aptitudes are so pronounced and peculiar as to disqualify them from taking the whole of any course organized with reference to the needs and abilities of a body of students. By this is not meant that students, generally speaking, should take up only those studies for which they have a distinct taste or fitness. The great majority of students may, consistently with making full use of their special gifts, pursue studies and exercises for which they have a lower, perhaps a much lower, degree of qualification. But it sometimes, it indeed not infrequently happens, that a student of decided abilities in some directions, is deaf, dumb, and blind so far as certain studies are considered. Whatever is addressed to him from such a quarter means absolutely nothing. Sometimes, indeed most commonly, such a disqualification for a whole class of studies or exercises is found in connection with very ordinary abilities; at other times it is found to consist with the capability for first-rate work in the directions which nature has pointed out; in instances, it is even compatible with tastes and aptitudes which constitute genius.

To say of all the students of an institution, that, on the penalty of foregoing instruction entirely, they shall take the whole of any one, even of several optional courses, is, in the case of students of the class indicated above, not merely to demand what is a sheer waste of time and strength: it also involves experiences in the study-room and in the class-room which are prejudicial to the student's ambition and self-respect, which inevitably lower his stand-

ard for the performance of duty, and which tend, in the case of all but the strongest minds, to impair intellectual integrity and honesty.

To all the students of this school, the Faculty hold out two inducements to become and remain regular students: first, the degree of the Institute, which is, for professional purposes, of a distinct and constantly increasing value; secondly, the consideration that we can, other things equal, do more in the same time for a regular than for a special student, the former's work being, in the nature of the case, better adjusted, more accurately measured, and subject to more of inspiration and impulse from the teacher and from the class.

After offering the student these two inducements, the Faculty leave it to the determination of himself and of his parents or guardian, whether he shall enter a course leading to the degree of the Institute, or take up studies specially suited to his own needs, tastes, and abilities.

At the same time, the Faculty do not purpose to admit anarchy into the studies and exercises of the Institute. A standing committee of the Faculty is charged with the scrutiny of the attendance papers of all special students, to see that the several studies taken hold a reasonable relation to each other, and that the amount of work involved is fairly adequate to occupy the scholar's time and energies. As to the performance of the work actually undertaken, the requirements are not less severe in the case of special than of regular students.

Thirdly. But perhaps an even more important function which the system of special students performs with us is one which may be called an administrative function. It is the steady purpose of the Faculty, not to confer the degree of the Institute upon any man who has not taken a thoroughly satisfactory course. Merely passing the several successive examinations, grazing every corner, will not answer: the student must have gone through the required studies and exercises with something of liberality, with

something over and to spare. Merely to have done the prescribed work, under the guidance and superintendence of his teachers, will not answer: he must have proved, by sustained thesis work, continued through several months, his ability to do original work, to plan and carry through a professional investigation by himself.

This standard the Faculty have unfalteringly maintained, even through the period of deepest darkness in the history of the Institute. The system adopted for the classification of students enables this to be done with the least possible harshness. On the one hand, the student who has, at any stage in the course, failed to do all that ought to be required of a candidate for a degree is not necessarily thrown out of the school; and, on the other hand, the Faculty are relieved from that painful pressure which rests upon all instructors where the old-fashioned class system is maintained, to allow students, in spite of specific deficiencies, and in spite of a generally low performance of work, to go forward, because it seems cruel to drop them, and put a stop to their scholarly career. In this school, when a student for any reason falls below the standard of what is required, after a fair trial, he becomes a special student, not by vote of the Faculty, but *ipso facto*. He is thereafter permitted to continue in all subjects in which he has done well, and to begin any new study which is dependent on these. Whenever he feels strong enough to put himself again in course for a degree, he is at liberty to present himself, at reasonable intervals, for examination in the matters in which he was found deficient. It is always competent for him to prove, if he can, that he is prepared to resume standing as a regular student. In this way, it often happens that a student who, from deficiencies of early instruction or from natural tardiness of development, could not have kept up with a class, and satisfactorily completed a course in four years, appears, at the end of the fifth year, as a very successful candidate for the degree of the Institute, with the highest promise of usefulness.

THE COURSES OF INSTRUCTION.

The following table exhibits the number of persons who have graduated within each of the several courses at each succeeding year, since the first diplomas were conferred in 1868. In this table, the term "General Course" will be understood to embrace alike the "Science and Literature" Course of the period 1868–1880, and the Elective and General Courses of the period subsequent.

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering.	Architecture.	Chemistry.	Metallurgy.	Electrical Engineering.	Natural History.	Physics.	General Courses.	Total.
1868. . .	6	1	6	..	..	..	..	..	..	1	14
1869. . .	2	2	..	..	1	..	..	..	..	..	5
1870. . .	4	2	2	..	1	..	..	..	..	1	10
1871. . .	8	2	5	..	2	..	..	..	..	..	17
1872. . .	3	1	5	..	3	..	..	..	..	..	12
1873. . .	13	1	3	1	7	..	..	..	..	1	26
1874. . .	10	4	1	1	..	..	..	..	..	2	18
1875. . .	10	6	6	1	1	..	..	..	1	2	27
1876. . .	12	9	7	..	5	1	..	1	4	4	43
1877. . .	12	6	8	4	2	..	..	..	..	..	32
1878. . .	8	2	2	3	3	..	..	..	..	1	19
1879. . .	6	8	3	1	3	..	..	1	1	..	23
1880. . .	3	..	3	..	1	..	..	..	..	1	8
1881. . .	3	5	6	3	8	..	..	1	..	2	28
1882. . .	2	5	5	3	6	..	..	1	1	1	24
1883. . .	3	7	4	1	3	..	..	..	..	..	18
1884. . .	5	6	13	..	12	..	..	..	..	..	36
1885. . .	4	6	8	2	4	..	2	..	..	1	27
Total . .	114	73	87	20	62	1	2	4	7	17	387
Deduct names counted twice											2
											385

In the following table appears the distribution of the 228 regular students of the three upper classes among the several courses : —

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Electrical Engineering.	Natural History.	Physics.	General Course.	Total.
4th year class,	11	19	8	1	6	7	1	..	..	53
3d " "	11	19	10	2	5	11	1	1	3	63
2d " "	22	36	8	7	12	23	2	..	2	112
Total . . .	44	74	26	10	23	41	4	1	5	228

THE WORK OF SPECIAL STUDENTS.

The 194 special students in the School of Industrial Science cannot be classified systematically; but the following table exhibits the number of special students pursuing each particular branch of study, according to the attendance papers filed by them, and approved by the Faculty:—

NUMBER OF SPECIAL STUDENTS ATTENDING EXERCISES IN THE FOLLOWING DEPARTMENTS OF STUDY OR PRACTICE.

Architecture	40	German	85
Applied Mechanics	44	Mathematics	97
Chemistry	59	Mechanical Engineering	52
Civil Engineering	23	Military Drill	9
Mechanical Drawing	18	Mining and Metallurgy	20
Descriptive Geometry	30	Physics	87
English	72	Shop Work	60
French	42		
Geology	23		

Total number of entries, by special students	761
Total number of special students	194
Average number of entries	3.9

It may be of interest to note the numbers of students, either regular or special, pursuing certain leading branches of study, in each of the four years, which are as follows:—

	First Year.	Second Year.	Third Year.	Fourth Year.	Total.
Mathematics	208	148	87	9	452
Chemistry	217	35	32	19	303
English	197	133	67	..	397
French	216	..	..	..	216
Physics	..	159	92	17	268
German	..	153	105	5	263
Shopwork *	..	93	44	28	165

A still further increase of the instructing staff of the Institute has been required during the year.

The number of instructors of all grades, excluding those persons who are announced as lecturers for the year, is 62 against 57 last year. This increase has been mainly due to the very high specialization of work in the departments of Mechanical and Electrical Engineering, and to the great extension of drawing-room and laboratory practice in all departments.

The number of professors in the school is now 14; of associate professors, 6; of assistant professors, 7; of instructors, 17; of assistants, 18.

The following table shows the number of teachers of each recognized grade in each year since the foundation of the school: —

* Exclusive, of course, of the students of the School of Mechanic Arts. The corresponding total last year was 124.

Year.	Professors.	Associate Professors.	Assistant Professors.	Instructors.	Assistants.	Total.
1865–66 . .	10	..	..	.	..	10
1866–67 . .	12	..	..	2	..	14
1867–68 . .	12	..	1	2	2	17
1868–69 . .	13	..	..	6	1	20
1869–70 . .	16	..	1	6	2	25
1870–71 . .	18	..	2	7	5	32
1871–72 . .	21	..	2	11	1	35
1872–73 . .	23	..	2	9	1	35
1873–74 . .	20	..	3	10	4	37
1874–75 . .	20	..	3	7	3	33
1875–76 . .	23	..	..	6	8	37
1876–77 . .	21	..	..	4	10	35
1877–78 . .	20	..	..	3	14	37
1878–79 . .	18	..	..	7	12	37
1879–80 . .	16	..	..	7	8	31
1880–81 . .	15	..	2	6	7	30
1881–82 . .	17	..	3	6	11	37
1882–83 . .	16	..	3	10	11	40
1883–84 . .	15	..	8	15	10	48
1884–85 . .	14	3	11	15	14	57
1885–86 . .	14	6	7	17	18	62

Among the changes of the year has been one which calls for more than a passing notice. Professor Charles H. Wing has, after ten years of service, resigned the chair of analytical chemistry, at the imperative demands of private interests. The members of the corporation have no need to be told how great has been the contribution made by Professor Wing to the upbuilding of this School of Industrial Science; but I desire to put upon record my own deep sense of the value of his services. Few, indeed, of those who have been connected, in any capacity, with the Institute of Technology since its foundation in 1865, have done more to give it direction and impulse. His soundness of judgment, thoroughness of knowledge, and steadiness of will have not only made him eminently useful in his own department of instruction, but have constituted him one of the most trustworthy of advisers in regard to the general policy of the school and upon the multitudinous questions of detail arising in the course of administration.

Upon the resignation of Professor Wing, Professor Thomas M. Drown was appointed to the chair of analytical chemistry. He accepted the appointment, and entered on his duties at the opening of the school year.

Mr. Drown received the degree of Bachelor of Arts, in 1859, from the Philadelphia High School; and, in 1862, the diploma of Doctor of Medicine from the University of Pennsylvania. During 1862–63 he pursued advanced studies in the Sheffield Scientific School at New Haven; during 1863–65 he studied under Professor Wolcott Gibbs in the Lawrence Scientific School of Harvard University; during 1865–66 he was a student in the Freiberg Mining Academy of Saxony; during 1866–68 he studied under Bunsen in Heidelberg. During the academic year 1869–70, he was instructor in metallurgy in the Lawrence Scientific School. In 1871 he became Secretary of the American Institute of Mining Engineers, in which office he continued until 1883. In 1875 he was appointed professor of analytical chemistry in Lafayette College, Easton, Penn., resigning therefrom in 1883.

During the year Assistant Professors Holman, Wells, and Norton have been deservedly advanced to the grade of Associate Professors in their several departments.

Early in the school year, Assistant Professor Charles H. Fisher was compelled, by ill-health, to resign from the department of mechanical engineering; Assistant Professor Peabody has, in consequence, been transferred from the department of applied mechanics to that of mechanical engineering, with the title of Assistant Professor of Steam Engineering; and Mr. Jerome Sondericker, lately of the Illinois Industrial University, was appointed instructor to assist Professor Lanza in the instruction in applied mechanics.

At the opening of the present school year, Dr. Joseph J. Skinner, formerly of the Sheffield Scientific School of New Haven, was appointed instructor in mathematics; and Mr. William Cook, formerly of Harvard University, was ap-

pointed instructor in modern languages. These appointments have greatly strengthened the instructing-staff in the two departments concerned.

LABORATORIES.

The alterations and additions effected among the laboratories of the school during the year will seem slight in comparison with the great and almost revolutionary changes of recent years. The increase of students in the department of industrial chemistry, under the vigorous administration of Associate Professor Norton, has made necessary an addition to the laboratory of that department, which has been secured at the expense of the chemical supply-room. The space thus obtained has been utilized as a dyeing-room, and has been fitted up with kettles, water-baths, and various working-models of machines used in this industry.

The large suite of rooms, occupied since 1883, in friendly partnership by the laboratories of applied mechanics and of mechanical engineering, both under the charge of Professor Lanza, were, during the summer, still further equipped with a great variety of new apparatus and machinery, fully doubling the capacity of these laboratories for the instruction of students. A new machine for testing the strength of materials by tensile and compressive strains, a machine for making time-tests of timber, an additional condenser, a mercury column, a six-inch turbine, an additional friction-brake, and a suite of apparatus for testing the friction of belting and the strain upon shafting, have been added to this laboratory, which is now in thorough working-order, with a wealth of appliances for practical tests and scientific investigations in this most interesting department of instruction, which already contains one-third of the students of the three upper classes.

During my trip to France, in June of the last summer, I enjoyed the privilege of visiting several of the technical and professional schools of Paris; and, while subsequently

in England, I visited the Universities of Cambridge, Edinburgh, Glasgow, and St. Andrew's, the University Colleges of Bristol and Dundee, the new Science College of Yorkshire, in Leeds, the Finsbury Technical College, the Royal School of Mines, and the new City and Guilds Institute at South Kensington, London. During the past few years enormous expenditures have been made towards the equipment of institutions for scientific and technical instruction in the United Kingdom; and this work, so long delayed, is still proceeding with great vigor under most enlightened direction. To say that I saw no laboratories, whether of chemistry, of physics, or of mechanics, which are equal to our own in capacity or appointments, is not incompatible with the remark that I derived much in the way of instruction from visiting these institutions, and much in the way of inspiration from conference with the able and learned scholars who are shaping "the new education" abroad. Of all that I saw, that which I most admired and most coveted for our own country and for this our own school was the Industrial Museum in the Rue St. Martin, connected with the École Centrale of Paris. May we not hope that, at some not distant date, the munificence of the citizens of Boston will enable the Institute of Technology to place, in an equally striking and picturesque arrangement, the complete history of American invention and American industry; to exhibit in spacious and well-lighted halls, in orderly succession, in their choicest forms, the machinery, the processes, and the products of every branch of manufacture, — alike for the advantage of our own students, and for the entertainment and instruction of the residents and the visitors of this beautiful city?

During the summer, also, Dr. Williams, of the corporation, visited Zurich, Munich, and other seats of chemical instruction, with a view to studying the problem of instruction in industrial chemistry, and obtaining suggestions for the further equipment of that portion of our own laboratories. I cannot doubt that the service of the Institute,

on this side, will derive immediate benefit from these observations and studies of Dr. Williams.

Of the deportment of the scholars of the Institute during the year covered by the report now offered; of the respect paid to the few and simple rules of the school; of the attention given to the prescribed studies and exercises; of the progress made in scientific acquirements, in professional accomplishments, and in manly character; of the relations between teacher and pupil here; of the general spirit pervading the institution, — I have nothing to say but what is gratifying in the present and encouraging for the future. It is one of the felicities of an instructor in this school, that his duty calls him to deal with young men who, in general, appreciate acutely the privileges which the sacrifices of their friends have secured for them; who will not remain content with a low standing, and a shabby performance of prescribed tasks; who are laying the foundations of future success by doing present duties faithfully and well; who come hither to work, and who, in all but a comparatively insignificant number of instances, do work as hard and as long as their teachers would desire; among whom the ambition for display, the taste for frivolity, the aptitude for vicious indulgences, are at the minimum, and whose dominant sentiment instinctively prescribes the right and outlaws the wrong. That excellent teacher who has just left the chair of analytical chemistry has told me, that, in his ten years of service, he has never had a dozen "black sheep" in his laboratory, — men whom in spite of faults and failings he could not respect, and of whom he felt reluctant to be the teacher. That was a noble tribute for a teacher whose own ideal of character and conduct was so high, to pay to a body of students so large and so variously com posed. Of its strict truthfulness I entertain no doubt. There is something in the atmosphere of the place; in the character of the studies and exercises pursued; in the distinctness with which the students see the purpose and object of those studies and exercises, as bearing upon their

own success and happiness in life; in the close and familiar contact of teacher and student, at the bench, across the table, around the machine; doubtless, also, in the class of students who are attracted to the school, — which makes the work of instruction here singularly agreeable and inspiring.

I cannot close this paper without adverting to the necessity, so strongly insisted upon in my last report, which exists for large additional endowments to secure the future of this school; to enlarge its means of present usefulness; and, both through the reduction of the prescribed tuition-fees and through the establishment of a certain number of free scholarships, to bring the advantages of the Institute of Technology within the reach of a larger number of the youth of the Commonwealth and of the country.

All of which is respectfully submitted.

FRANCIS A. WALKER, *President.*

71
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Mass. Institute of Technology.

President's Report,

Dec. 8, 1886.

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To the Corporation of the Massachusetts Institute of Technology.

DURING the twelve months which have passed since I presented my last annual report, the school year 1885–86 has come to its close, and the school year 1886–87 has begun; the one with results altogether fortunate, the other under the fairest auspices.

The class of 1886 graduated on the 1st of June. Of the 62 students of the fourth year, who were candidates for the degree of Bachelor of Science, 59 were admitted to that grade by your authority, upon the recommendation of the Faculty of the School of Industrial Science.

The public exercises of the day were after the severe and simple form set by the first President of the Institute. The class thus graduating was one of exceptional strength of character and thoroughness of scholarship. There could be no higher example of what this school aims to effect than is afforded by the graduating theses of the class of 1886, taken in connection with the records of its members during the four years of their stay among us.

Those years had been spent in the work, not of decoration, but of construction; not in polishing the surface, but in building up the substance of mind and character. Little time or thought had been expended in memorizing facts previously ascertained, or in rehearsing the opinions of others; but from the first day's exercise in the laboratory of general chemistry, on through all their course, these young men had been taught to see with their own eyes, and think with their own minds, weighing, probing, analyzing, testing, for themselves, the substances and appearances which formed the subjects of their study, until through the development of their perceptive powers, through the formation of a habit of careful, discriminating, and minute observation, and through the exercise of the

faculty of judgment, the least gifted of them had become capable, as evidenced by the severe test of our thesis requirement, of selecting a field of investigation, isolating the subject-matter, eliminating for the time every thing alien or adventitious, providing all the conditions of a true experiment, and, through the application of approved tests, making an actual contribution to human knowledge. This is what we deem Education, in the best and fullest sense of that term.

THE NEW YEAR.

The total number of persons registered in all the departments and schools under the control of this corporation, for the school year 1886–87, is 738, against an aggregate, last year, of 730.

Omitting from consideration the students of the Lowell Free School of Practical Design, the number this year is 675 against 669 last year. Still further excluding the students of the School of Mechanic Arts, we find the number of students in the School of Industrial Science, the proper Institute of Technology, to be 637 against 609 last year, showing an increase of 28, or four and a-half per cent.

The following table exhibits the number of students in the School of Industrial Science each year from the opening of the Institute to the present time.

Year.	No. of Students.	Year.	No. of Students.
1865–66	72	1876–77	215
1866–67	137	1877–78	194
1867–68	167	1878–79	188
1868–69	172	1879–80	203
1869–70	206	1880–81	253
1870–71	224	1881–82	302
1871–72	261	1882–83	368
1872–73	348	1883–84	443
1873–74	276	1884–85	579
1874–75	248	1885–86	609
1875–76	255	1886–87	637

The aggregate for 1886–87 is divided among the several classes as follows:—

Graduate students, candidates for advanced degrees	2
Regular students, Fourth Year	57
" " Third "	87
" " Second "	98
" " First "	198
Special students	195

Approximately assigning the special students to classes according to the predominant studies pursued by them, we should reach the following statement of the division of the whole body among the several years.

Class.	Regular.	Special.	Total.
Graduates	2	–	2
Fourth year	57	25	82
Third year	87	48	135
Second year	98	64	162
First year	198	58	256
	442	195	637

STATISTICS OF EXAMINATIONS.

The results of the applications for admission to all classes of the School of Industrial Science thus far in the current school year, and of the examinations had thereupon, may be stated as follows:—

Forty-two were admitted without examination, either to the first year class, upon presenting certificates of clear admission to some college of reputable standing; or, upon the presentation of diplomas of graduation from some degree-conferring institution, classical or scientific, to our second or third year class as regular students, or to some department as special students; 158 were admitted upon examination, free of conditions; 80 were admitted with one

condition imposed, 25 with two conditions, 7 with three conditions; 40 applicants were rejected upon examination; 2 were admitted as special students, upon examination in the studies specially requisite to the partial courses which they proposed to follow.

The total number of applicants appears, therefore, to have been 354. Of those admitted upon examination, 61 have not thus far entered the school. In some instances, in the case of applicants heavily conditioned, this has been due to the advice of the Faculty that a longer period be taken for preparation; in some, to a change of plans, to sickness, or other causes.

There is reason for believing that not a few young men graduating from the high schools of Boston and vicinity, but not intending to pursue their studies further, pass our examinations as a sort of brevet. Thus to take our examinations shows a not discreditable ambition on the part of these young men. A certificate of clear admission to the Institute gives a very handsome finish to a high school course; and, as no great addition to the labor of examination is involved, it need not be made a matter of complaint on our part.

The figures which have been given regarding the entrance examinations of 1886, taken in connection with those of 1885 and 1884, show a progressive improvement in the preparation of candidates for admission. Of the total number submitting to examination this year, 76 per cent were admitted free of conditions, or with but one condition attached, as against 70 per cent last year. This result is due mainly to a better understanding of the requirements for entrance to the Institute, and to greater care and pains taken by teachers of high schools and academies in meeting those requirements.

EXAMINATIONS AT DISTANT POINTS.

In addition to the entrance examinations held in Boston in June and September, 1886, examinations were also con-

ducted in June at Atlanta, Chicago, Cincinnati, Denver, Nashville, New York, Philadelphia, Montreal, San Francisco, St. Louis, St. Paul, and Washington, generally with the assistance of the superintendents of the city schools who co-operated with the Faculty in the most cordial manner.

STATISTICS OF RESIDENCE.

Thirty-two States of the Union, besides the Territory of Dakota and the District of Columbia, are represented on our lists of students. Canada, Belgium, Peru, and Japan have also sent us students.

Of the total number of 637, including special students, 402 are from Massachusetts, or 63.3 per cent of the whole; 84 are from other New England States; 151 from outside New England.

The following table shows the number of students of each specified class, from each State or foreign country.

State.	Candidates for Advanced Degrees.	Fourth Year.	Third Year.	Second Year.	First Year.	All Regu'r Students.	Special Students.	Total.
Arkansas	..	..	..	..	1	1	1	2
California	..	..	1	2	3	6	2	8
Connecticut	..	..	3	1	5	9	7	16
Dakota	..	..	..	..	1	1	..	1
Delaware	..	..	..	..	..	..	1	1
Dist. Columbia,	..	..	..	..	..	..	4	4
Georgia	..	1	..	..	1	2	1	3
Illinois	..	..	1	3	10	14	5	19
Indiana	..	..	..	..	1	1	1	2
Iowa	..	2	..	1	1	4	2	6
Kansas	..	1	..	1	..	2	..	2
Kentucky	..	..	..	..	1	1	3	4
Maine	..	4	..	3	5	12	8	20
Maryland	..	..	1	..	1	2	..	2
Massachusetts	1	38	62	68	127	296	106	402
Michigan	..	..	1	1	1	3	2	5
Minnesota	..	..	1	..	1	2	2	4
Mississippi	..	..	..	..	..	..	1	1
Missouri	..	..	..	..	..	..	1	1
Nebraska	..	..	..	1	..	1	1	2
Nevada	..	..	..	..	..	..	1	1
N. Hampshire	..	4	3	2	7	16	10	26
New Jersey	..	..	..	..	1	1	6	7
New York	..	2	3	3	9	17	7	24
Ohio	..	1	2	2	6	11	10	21
Oregon	..	..	1	..	..	1	..	1
Pennsylvania	1	..	1	4	3	9	4	13
Rhode Island	..	1	4	4	6	15	2	17
South Carolina,	..	..	..	1	..	1	..	1
Tennessee	..	..	..	..	..	..	1	1
Vermont	..	..	..	..	3	3	2	5
Virginia	..	..	1	1	..	2	1	3
W. Virginia	..	..	..	..	..	..	1	1
Wisconsin	..	..	1	..	2	3	..	3
Foreign Country.								
Belgium	..	..	..	..	..	..	1	1
Japan	..	..	1	..	..	1	..	1
Peru	..	..	..	..	1	1	1	2
Prov. of Quebec,	..	2	..	..	1	3	..	3
N. Brunswick	..	1	..	..	..	1	..	1

RESIDENCE OF MASSACHUSETTS STUDENTS.

It has been said that 63.3 per cent of all our students are from Massachusetts. All the counties of the State, except the small county of Dukes and Nantucket, send students to the Institute of Technology. Ninety-one cities and towns are reported on the lists. The first column of the following table shows the number of cities and towns in each county sending pupils to the Institute; the second column gives the aggregate number from each county. It appears that Suffolk furnishes us 144 pupils; Middlesex comes next, with 105; Essex, third, with 49; Norfolk, fourth, with 36.

County.	No. of Towns.	No. of Students.	County.	No. of Towns.	No. of Students.
Barnstable .	2	2	Middlesex . .	26	105
Berkshire . .	3	5	Norfolk . .	10	36
Bristol . . .	5	16	Plymouth . .	10	19
Essex . . .	17	49	Suffolk . . .	3	144
Franklin . .	1	2	Worcester . .	9	14
Hampden . .	3	7			
Hampshire .	2	3		91	402

The following is a list of the towns, twenty-one in number, which send four or more scholars to the Institute: —

Boston 140	Lynn 7	Fall River . . . 4
Newton 26	Plymouth . . . 6	Framingham . . 4
Cambridge . . . 11	Salem 6	Malden 4
Somerville . . . 10	Beverly 5	New Bedford . . 4
Brookline . . . 8	Haverhill 5	Stoughton . . . 4
Lowell 8	Melrose 5	Weymouth . . . 4
Hyde Park . . . 7	Newburyport . . 5	Winchester . . . 4
Lawrence . . . 7	Canton 4	

PROPORTION OF OLD AND OF NEW STUDENTS.

The following table exhibits, for each year of the school's history, the distribution of the total number of students

among two classes: first, those students whose names are found upon the catalogue of the year preceding; and, secondly, those students whose names appear as new names upon the catalogue of the year to which the statement relates: —

Year.	(1) Total No. of Students.	(2) No. of Students in the Catalogue of the previous year who remain in the Institute.	(3) No. of New Students entering before issue of Catalogue.	(4) Of those in column (3) the following number were regular first year Students.	(5) No. of New Students not of the regular first year class.
1866-67	137	34	103	58	45
1867-68	167	79	88	54	34
1868-69	172	82	90	50	40
1869-70	206	90	116	63	53
1870-71	224	109	115	71	44
1871-72	261	122	139	82	57
1872-73	348	173	175	112	63
1873-74	276	171	105	59	46
1874-75	248	159	89	35	54
1875-76	255	139	116	65	51
1876-77	215	130	85	31	54
1877-78	194	96	98	47	51
1878-79	188	99	89	34	55
1879-80	203	102	101	34	67
1880-81	253	121	132	62	70
1881-82	302	136	166	86	80
1882-83	368	173	195	114	81
1883-84	443	231	212	140	72
1884-85	579	311	268	186	82
1885-86	609	369	240	177	63
1886-87	637	379	258	190*	68

It appears from the foregoing, that the number of students remaining over has been increased by 10, while the number registered for the first time is larger by 18; making the net gain, as previously stated, 28.

AGES OF STUDENTS ON ENTRANCE.

Another class of facts, first presented in the report of last year, is given for the current year; those, namely,

* In addition, 8 students are repeating the first year.

which relate to the ages of our students upon entrance. The regular students of the first year class number 198. From these we should except three cases of students of unusual ages; viz., two of 22 and one of 23 years. These deductions leave 195 as the number of students whose ages have been made the subject of computation.

The results appear in the following table, in comparison with the corresponding results for 1885–86.

Period of Life.	1885–86.		1886–87.	
	Half-Year Groups.	Yearly Groups.	Half-Year Groups.	Yearly Groups.
16 to 16½ years	11		10	
16½ to 17 years	16	27	19	29
17 to 17½ years	24		16	
17½ to 18 years	20	44	33	49
18 to 18½ years	42		38	
18½ to 19 years	23	65	23	61
19 to 19½ years	21		21	
19½ to 20 years	11	32	15	36
20 to 20½ years	6		9	
20½ to 21 years	3	9	6	15
21 to 22 years	5	5	5	5
	* 182	182	† 195	195

From the foregoing tables it appears that the average age of the 195 students taken for this comparison, the present year, is 219.91 months, or 18 years, 3 months, and 27 days. This compares with the corresponding figures relating to the five previous entering classes, as follows: —

	Av. Age in Months.		Av. Age in Months.
Class of 1885	220.50	Class of 1888	220.66
Class of 1886	218.45	Class of 1889	218.53
Class of 1887	218.88	Class of 1890	219.91

* Five students being excepted from the computation, two being of unusual age, the ages of three not being recorded.

† Three being of unusual age, as stated.

PROPORTION OF REGULAR AND OF SPECIAL STUDENTS.

Another table which has been prepared exhibits both the absolute number of regular and of special students, as by the catalogue of each successive year, and also the proportion existing between these two classes: —

Year.	No. of Regular Students.	No. of Special Students.	Total No. of Students.	Percentage.	
				Regular.	Special.
				Per cent.	Per cent.
1865-66	64	8	72	89	11
1866-67	110	27	137	80	20
1867-68	124	43	167	74	26
1868-69	105	67	172	61	39
1869-70	125	81	206	71	29
1870-71	143	81	224	64	36
1871-72	180	81	261	69	31
1872-73	235	113	348	68	32
1873-74	182	94	276	66	34
1874-75	170	78	248	69	31
1875-76	182	73	255	71	29
1876-77	134	81	215	62	38
1877-78	117	77	194	60	40
1878-79	103	85	188	55	45
1879-80	110	93	203	54	46
1880-81	140	113	253	55	45
1881-82	164	138	302	54	46
1882-83	219	149	368	60	40
1883-84	272	171	443	61	39
1884-85	368	211	579	64	36
1885-86	415	194	609	68	32
1886-87	442	195	637	69	31

It will be seen that the tendency noted in the reports of the two last years, towards a progressive increase in the proportion of students taking the full regular course, still continues. The policy of the Institute regarding special students was very fully presented in the last annual report.

GRADUATES OF OTHER COLLEGES.

It has been stated that two students who have graduated from this school with the degree of Bachelor of Science are pursuing courses of study in the Institute as candidates for advanced degrees.

In addition, we have nineteen students, graduates of other institutions, pursuing courses of study with us, either as regular students, candidates for the Bachelor's degree, or as special students. Of these, nine are graduates of Harvard University, two of Brown University, while one comes from each of the following institutions: Baldwin University, the University of New Brunswick, the University of the Pacific, the University of Vermont, Belmont College, Columbian University, Yale College, and Ohio State University.

Of the nineteen, three are regular students of the fourth year in civil, in mechanical, or in electrical engineering; two are regular students in mechanical engineering, one in civil, and one in electrical engineering, in the third year. The remainder are registered as special students; six of them devoting themselves to chemistry and metallurgy, three to architecture, one to civil engineering, one to mechanical engineering, and one to physics.

In the earlier years of the Institute, the crowded condition of our laboratories, and the intense occupation of our teachers in undergraduate instruction, left little opportunity for work in advance of that demanded by our first degree, that of Bachelor of Science. The ampler space and more elaborate equipment of our present laboratories, the higher specialization of the services of the school, and the larger teaching staff have, within the past two or three years, encouraged the Faculty to offer facilities for study and research far beyond that of the required courses; and it is my earnest hope, that more and more the stronger men of our graduating classes will decide to remain for one or more years of advanced work, and become candidates for the advanced degrees, — those of Master of Science, Doctor of Philosophy, and Doctor of Science, — which the corporation has authorized to be conferred.

The presence of graduates of other institutions, as candidates for our degree of Bachelor of Science, or as special students in the various undergraduate departments, has ong been a feature on our lists.

Serious difficulties in classifying such students, and in arranging their desired courses of study, have always been encountered, from the great diversity existing in the undergraduate instruction of the institutions from which they came, and even more from the widely different significance to be attached to identical announcements on the schedules of study in such institutions. Especially has embarrassment been caused by the manner in which the mathematics are taught in many of the colleges of the country. With us the mathematics are taught, not for themselves, but for their uses: instructors employ methods directed to give the pupils command of algebra, geometry, analytics, or the calculus, as tools; the pupils, on their part, having early, perhaps immediate, occasion for such applications of their mathematics, give themselves to their work with greater earnestness and directness; while the constant reference to mathematical principles in the drawing-room or laboratory emphasizes these principles in the mind.

THE COURSES OF INSTRUCTION.

For the first time for several years, we have in the fourth year class one or more candidates for the Bachelor's degree in each department of the Institute.

The following table presents the number of students in each of the regular courses. It will be seen that this statement relates to the second, third, and fourth years; choice of courses being made only at the end of the first year.

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Electrical Engineering.	Natural History.	Physics.	General Course.	Total.
4th year class,	8	19	8	1	7	9	1	1	3	57
3d " "	15	30	6	4	9	19	3	..	1	87
2d " "	22	26	5	8	8	24	.	1	4	98
Total. . .	45	75	19	13	24	52	4	2	8	242

The following table exhibits the number of persons who have graduated within each of the several courses, at each succeeding year since the first diplomas were conferred in 1868. In this table, the term "General Courses" will be understood to embrace alike the "Science and Literature" Course of the period 1868–1880, and the Elective and General Courses of the period subsequent.

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering.	Architecture.	Chemistry.	Metallurgy.	Electrical Engineering.	Natural History.	Physics.	General Courses.	Total.
1868 . .	6	1	6	..	..	..	..	..	..	1	14
1869 . .	2	2	..	..	1	..	..	..	..	..	5
1870 . .	4	2	2	..	1	..	..	..	..	1	10
1871 . .	8	2	5	..	2	..	..	..	..	..	17
1872 . .	3	1	5	..	3	..	..	..	..	..	12
1873 . .	13	1	3	1	7	..	..	..	..	1	26
1874 . .	10	4	1	1	..	..	..	..	..	2	18
1875 . .	10	6	6	1	1	..	..	..	1	2	27
1876 . .	12	9	7	..	5	1	..	1	4	4	43
1877 . .	12	6	8	4	2	..	..	..	..	..	32
1878 . .	8	2	2	3	3	..	..	..	..	1	19
1879 . .	6	8	3	1	3	..	..	1	1	..	23
1880 . .	3	..	3	..	1	..	..	..	..	1	8
1881 . .	3	5	6	3	8	..	..	1	..	2	28
1882 . .	2	5	5	3	6	..	..	1	1	1	24
1883 . .	3	7	4	1	3	..	..	..	..	..	18
1884 . .	5	6	13	..	12	..	..	..	..	..	36
1885 . .	4	6	8	2	4	..	2	..	..	1	27
1886 . .	9	23	7	1	7	..	10	1	..	1	59
Total .	123	96	94	21	69	1	12	5	7	18	446
Deduct names counted twice											2
											444

THE WORK OF SPECIAL STUDENTS.

The 195 special students in the School of Industrial Science cannot be classified systematically; but the following table exhibits the number of special students pursuing each particular branch of study, according to the attendance papers filed by them, and approved by the Faculty: —

NUMBER OF SPECIAL STUDENTS ATTENDING EXERCISES IN THE FOLLOWING DEPARTMENTS OF STUDY OR PRACTICE.

Architecture	51	German	81
Applied Mechanics	47	Mathematics	92
Chemistry	71	Mechanical Engineering	47
Civil Engineering	25	Military Drill	16
Mechanical Drawing	20	Mining and Metallurgy	23
Descriptive Geometry	21	Physics	93
English	68	Shop Work	44
French	46	Heating and Ventilation	10
Geology, etc.	36		

Total number of entries, by special students	791
Total number of special students	195
Average number of entries	4.1

It may be of interest to note the numbers of students either regular or special, pursuing certain leading branches of study, in each of the four years, which are as follows :—

	First Year.	Second Year.	Third Year.	Fourth Year.	Total.
Mathematics	211	134	105	17	467
Chemistry	227	26	29	20	302
English	209	117	69	..	395
French	210	13	..	..	223
Physics	..	141	106	22	269
German	..	131	113	10	254
Shopwork *	..	73	50	26	149

THE CORPS OF INSTRUCTORS.

A still further increase of the instructing staff has been required during the year.

The number of instructors of all grades, excluding those persons who are announced as lecturers for the year only, is 69, against 62 last year. This increase has been in part due to the increasing specialization of work in the departments of mechanical and electrical engineering, and of

* Exclusive of students in the School of Mechanic Arts.

drawing-room and laboratory practice in all departments; in part to the increase in the size of the classes, requiring a greater number of divisions for the purposes of recitation or field work.

The number of professors in the school is now 12; of associate professors, 7; of assistant professors, 6; of instructors, 27; of assistants, 17.

The following table shows the number of teachers of each recognized grade in each year since the foundation of the school.

Year.	Professors.	Associate Professors.	Assistant Professors.	Instructors.	Assistants.	Total.
1865–66 . .	10	..	..	..	..	10
1866–67 . .	12	..	..	2	..	14
1867–68 . .	12	..	1	2	2	17
1868–69 . .	13	..	..	6	1	20
1869–70 . .	16	..	1	6	2	25
1870–71 . .	18	..	2	7	5	32
1871–72 . .	21	..	2	11	1	35
1872–73 . .	23	..	2	9	1	35
1873–74 . .	20	..	3	10	4	37
1874–75 . .	20	..	3	7	3	33
1875–76 . .	23	..	..	6	8	37
1876–77 . .	21	..	..	4	10	35
1877–78 . .	20	..	..	3	14	37
1878–79 . .	18	..	..	7	12	37
1879–80 . .	16	..	..	7	8	31
1880–81 . .	15	..	2	6	7	30
1881–82 . .	17	..	3	6	11	37
1882–83 . .	16	..	3	10	11	40
1883–84 . .	15	..	8	15	10	48
1884–85 . .	14	3	11	15	14	57
1885–86 . .	14	6	7	17	18	62
1886–87 . .	12	7	6	27	17	69

The changes of the past year among our professors and other teachers have been many and important. For the first time in the twenty-one years of our history, an active member of the corps of instructors has died in service. Professor Nichols departed this life in Hamburg, on the

14th of July, from the effects of a critical surgical operation, undertaken, though with little expectation of a favorable result, for his relief from the distressing malady against which for many years he had fought with marvellous heroism.

William Ripley Nichols was born in Roxbury, on the 30th of April, 1847. After preparing himself for Harvard College, he entered the Institute of Technology in 1865. Graduating from the chemical course as one of the five members of the class of 1869, after a career in which he was not less remarked for scholarly grace than for scientific strength, he was at once selected as an assistant in chemistry, and in 1872 was made professor of general chemistry, which chair he held until his death. His own strong predilections, rather than any purpose of the government or Faculty, led him to add to his duties a gradually extending course of instruction in sanitary chemistry.

During the year 1881–82, Professor Nichols so far yielded to the entreaties of his colleagues as to relinquish temporarily his duties at the Institute, and to seek, through repose, the restoration of his health, long before deeply undermined by excessive labors. Resuming his work, with but slight improvement observable in his condition, he again took up his burden with an extraordinary power of will, bearing its increasing weight to the end with a serene courage rarely seen among men. If ever one of our race proved the utmost effects of resolution and fortitude in contesting the progress of fatal disease, that man was William Ripley Nichols.

As an investigator, Professor Nichols early attained eminence in that department known as sanitary chemistry, especially as related to the water-supply of cities. Here he had few equals; while his conservatism of temper and his sterling conscientiousness kept him from the errors and faults into which so many promising students in this field have fallen.

As a teacher, Professor Nichols was a clear expositor,

strong and terse in argument, apt in illustration, neat and effective in manipulation. To faithful and ambitious students he was, in his calm, steady, lofty way, a constant source of inspiration and encouragement.

As a disciplinarian, dealing with mixed classes of young men, often ill-trained in their previous studies and exercises, and not always duly attentive and diligent, he was, let it be said in that spirit of truthfulness of which his own character and career afford so shining an example, somewhat severe. Dealing heroically with his own life, health, hopes, pleasures; setting for himself a lofty standard, and holding himself unflinchingly up to its full height, he was, in a degree, deficient in toleration for faults and errors in half-formed or ambiguous characters.

As a member of the Faculty, his influence was, from first to last of his connection with it, altogether and highly useful. No man did more — doubtless all my colleagues of the Faculty would hasten to say, no man did so much — to create and maintain the peculiar character of this school. He was, beyond all others, master of its rules and methods of procedure. His moral courage and lofty principles of action not only kept him from faltering in difficult situations, in doubtful cases, but were a positive force to hold up the hands and the hearts of his colleagues. Here he was eminently a leader, — and that not by any desire to lead, or a disposition to manage or govern; not from any wilfulness of temper, or through any dialectical or rhetorical artfulness: but solely and always by the clearness of his reasons, the thoroughness of his convictions, the perfect consistency of his views and purposes.

In the middle of the year, Professor George L. Vose withdrew, on his own instance, from the chair of civil engineering, to which he was appointed in 1881. Although Professor Vose's resignation was due to a difference of views between himself and the Faculty of the school, as to the courses of instruction, his colleagues have not failed to do justice to his very high professional acquirements and

abilities, to his sincerity and moral earnestness, and to the great kindliness and generosity of his nature.

Still another loss which the Institute has sustained during the year has been in the violent death, through a distressing accident, of Mr. William Cook, instructor in the modern languages.

Mr. Cook was born in 1842. He entered Yale College in the class of 1861. After graduation, he entered the army, and served till the close of the war then in progress. He subsequently spent several years abroad, engaged in the study of modern languages. Upon his return, he became instructor and afterwards assistant professor of German in Harvard University, where he remained until 1881. On a wider field, he rendered valuable services to his profession as the English editor of several important French and German works.

In 1885 Mr. Cook was appointed instructor, to fill an original vacancy caused by the increase in the number of students in the department of modern languages. During his single year in the Institute he had achieved a marked success, commanding the respect and winning the regard of his pupils. He had been engaged to continue his work in the school the coming year, after a promotion which testified to the sense entertained of the value of his services, and was on the point of resuming his instruction, when cut off by the accidental discharge of a fowling-piece, at Chatham, Mass., on the 27th of August, 1886.

The vacancies caused by the casualties recited have been temporarily filled as follows: —

The instruction in general chemistry is given the present year by Assistant Professor Pope, of the department of analytical chemistry. Professor Pope also gives the instruction in the theoretical chemistry of the second year. Professor Drown assumes the responsible charge of the instruction in sanitary chemistry; Mrs. Richards remaining the instructor in that department, as under Professor Nichols, assisted by Mr. Frederick Fox, jun., M.S. Mr.

Clement W. Andrews, A.M., gives the instruction in the theoretical chemistry of the third year.

Assistant Professor George F. Swain has been appointed associate professor of civil engineering, and placed in charge of that department, pending an appointment to the Hayward professorship.

Professor Swain graduated from the Institute with high honors in 1877. From 1880 to 1882 he was engaged as a special agent of the census office in investigating the water-power employed in manufactories on the Atlantic slope. The results of these investigations, accompanied by most valuable discussions of the geographical and meteorological conditions controlling the flow of water in the streams of that region, and its utilization for the purposes of manufacture, have been published by the United-States Government in several extended reports. In 1881 he was appointed instructor in Civil Engineering in the Massachusetts Institute of Technology, and in 1883 was advanced to the grade of assistant professor.

Some important changes in the nature of extending and diversifying the instruction given in this department will be mentioned in another connection.

During the course of the past year, Mr. Charles D. Jameson was appointed instructor in railroad engineering. Mr. Jameson was graduated from Bowdoin College, in the Engineering Department, in 1876. After graduation, he was almost constantly engaged in railroad engineering in the field until his appointment here. Three years of the time were spent on the Memphis and Charleston Railroad, and four and a half years on the Mexican Central Railroad.

To fill the vacancy caused by Mr. Cook's death, Dr. G. Theodore Dippold has been appointed instructor in modern languages. Dr. Dippold is a native of Frankfort-on-the Main, where he completed his course at the Gymnasium. After attending lectures at Heidelberg, he came to America, and first occupied a position as tutor in German in Harvard University, 1870–73. After this he was in-

structor in French and Anglo-Saxon in Boston University, 1874–83, where he took the degree of Ph.D. He was subsequently instructor in German in Wellesley College, and in 1883 at the Johns Hopkins University.

The great increase which has taken place in the number of students, especially of the first and second years, appeared to the Faculty and to the Executive Committee to require an important addition to the instructing staff in the department of history and political science; and, at the close of the last school year, the position of instructor in that department was offered to Dr. Davis R. Dewey, and by him accepted. Dr. Dewey graduated, with the degree of Bachelor of Arts, at the University of Vermont in 1879. For four years thereafter he was engaged in teaching, the greater portion of that time as principal of the high school in Hyde Park, Ill. From 1883 to 1886, he was a student in advanced courses of historical and political science in the Johns Hopkins University, Baltimore, from which he received the present year the degree of Doctor of Philosophy. Dr. Dewey has already made himself a reputation for good work in economic statistics and industrial history.

The department of architecture has been materially strengthened, during the year, by the appointment of Mr. Thomas O'Grady, jun., as instructor. Mr. O'Grady was a special student in architecture, at the institute, during the years 1878–80, and has since been engaged in the active practice of his profession in the city of Boston.

The following gentlemen, formerly assistants, have this year been appointed instructors in their several departments: Mr. Charles A. French (mathematics), Mr. George H. Barton (mineralogy), Mr. George R. Underwood (industrial chemistry), Mr. Fred. L. Bardwell (general chemistry), Mr. Aug. H. Gill (general chemistry), Mr. Arthur J. Purinton (mechanical engineering), Mr. Harry W. Tyler (mathematics), and Mr. Alfred L. Fitch (mechanical engineering).

CHANGES IN COURSES OF STUDY AND IN LABORATORY ACCOMMODATIONS.

The most considerable modification which has taken place in any of the courses of instruction during the past year has been in the department of civil engineering.

The rapid development of the technical sciences and the specialization of the various branches of civil engineering have so enlarged the field of professional work, as to make it desirable, that, among a numerous body of students like ours, some choice should be allowed as to the subjects of study to be extensively and minutely pursued, so that those who feel a special aptitude for making themselves highly expert in some one line, or who have peculiar outside reasons for doing so, may have the desired opportunity.

At the same time, it is fully recognized to be expedient for the great majority of students to cover nearly the whole familiar field of civil engineering study, in the uncertainty which necessarily exists in the case of most regarding the particular line of work to which circumstances will ultimately direct them.

In this view, the studies of the civil engineering department remain essentially the same as heretofore, down to the completion of the second year. During the third year, a few options are introduced, causing a certain, though as yet not considerable, branching-out of the course. In the fourth year, three widely different lines of study and practice are offered the student. The first is a general course, substantially the same with that heretofore pursued. The second is known as the railroad course, and is especially adapted to allow those students who are sufficiently confident of their future field of work, to qualify themselves in a far higher degree than is attainable in the general course, for service in surveying and locating railroad lines, in constructing and maintaining roadways, tracks, bridges, and terminals, and in taking part, should they in time be called to do so, in operating and managing roads. In addi-

tion to the regular course in political economy, the students of this class receive special instruction in the economics of transportation and in railroad book-keeping. Particular pains are taken to impress it upon the students that the engineer should be the friend and not the enemy of the finances of the road on which he is employed; that it is his part, not to build engineering monuments to display his skill and ingenuity, but to meet the exigencies of transportation as simply and cheaply as is consistent with strength, permanence, and security; that all unnecessary expenditures in meeting the demands of traffic and travel become a perpetual tax.

The third branch of the civil engineering department is styled the course in geodesy and topography, and is designed to qualify any who may desire it for work of the highest class in geodesy, topography, and field astronomy. It is not anticipated that this branch will ever be taken by many students; but it is deemed appropriate that a school of applied science should be prepared to give such instruction, while the need of men thoroughly trained in this way has long been felt in connection with the government surveys.

A tentative scheme for the civil engineering studies, as thus proposed to be modified, has already been put forth in pamphlet form. Advantage will be carefully taken of experience in the further development of the new lines of study.

During the past year, the appliances of the chemical laboratory have been materially increased in extent and the older apparatus has been perfected. The crowded condition of the sanitary laboratory rendered an increase of facilities necessary. The large room 36, New Building, was taken for a laboratory of sanitary chemistry, and equipped in a most thorough manner, thereby giving ample accommodation for thirty students; the small rooms 33 and 34 being surrendered by the chemical department, to be used for recitations. The laboratory of indus-

trial chemistry has been rendered more effective by the addition of numerous pieces of apparatus, and the dyeing-room has been put in successful operation during the year. Increased attention has been paid to teaching this branch of chemistry by excursions to manufacturing establishments. The laboratory for organic chemistry has been crowded during the whole year; and, if the present demand for men with this special training continues, increased facilities must soon be given for the prosecution of work in this direction.

Rooms 32 and 33 in the Rogers Building have been thrown together, and together with room 31 have been made into a suite, for the better accommodation of the departments of English, history and political science. Laboratory methods are being, as far as possible, introduced into the instruction in these branches.

The changes in the department of physics, chiefly in connection with the instruction in electrical engineering, have been rather of the nature of steady and marked, though gradual, advance in all directions, than of radical alterations. Our collection of apparatus for precise measurement is large, as is necessarily the case with such advanced instruction and such large classes; and the past year has added materially to our resources in this direction. In addition to the valuable and delicate measuring instruments which have been purchased, we are also in possession of an experimental dynamo-machine, constructed by two of our students in connection with their thesis-work, and particularly adapted for the study of the theory of such machines. New and valuable courses of lectures have been instituted, on the Precision of Measurements by Professor Holman, and on Quaternions by Professor Osborne; and additional courses will be opened during the present year. In the matter of original research, the laboratory has been busy; and during the year 1885–86, five papers have been published in the Proceedings of the American Academy of Arts and Sciences, while several

others are nearly ready for publication. Allusion should also be made to the increased number of exercises in heating and ventilation, and to the largely increased number of students from the Architectural, Biological, Mechanical, and Civil Engineering courses.

The changes in the departments of applied mechanics and mechanical engineering since last year have been in the nature of a further development of the courses laid out, and a more thorough systematizing of the work. The options of the fourth year have been entered upon earlier, thus giving opportunity for further extension of the scope of these studies. In the laboratories some new apparatus has been added. That for testing injectors, and that for calibrating wires, has been added; and machinery is now being introduced for testing the transmission of power by ropes, which will also enable us to extend further the belting tests, which have formed a prominent feature of the instruction in this laboratory during the past two years. The department has received a new Mack injector, and five grooved pulleys for ropes from the manufacturers in Glasgow.

THE NEED OF FURTHER ENDOWMENTS

More and more painfully, from year to year, we feel the need of large permanent endowments, to increase the present usefulness, and to secure the future, of the Institute. No school in the land is undertaking to do a work as large as ours, without twice, thrice, or four times our invested means. Few American institutions draw as much as one half their income from students' fees; many receive not more than one-third or one-fourth from this source. The Massachusetts Institute of Technology is obliged to meet not less than three-fourths of its expenses through tuition bills. This is not only a dangerous situation for any institution to occupy, but it is really serving upon new students

It should be remembered, that six short years ago, the total number of students registered in the School of Science

trial Science was 188; to-day it is 637. No corresponding increase of endowments has taken place. Nearly all of the additions to our means which have been made in the interval have necessarily gone to meet the absolute exigencies created by the great increase in the attendance upon the school. These 450 additional students have had to be accommodated, buildings erected, laboratories furnished, costly scientific apparatus provided for them.

While thus the increasing numbers of scholars at the Institute has involved larger and larger expenditures, both the logic of events and the rightful ambition of the Faculty and Corporation, have created continually new occasions for the use of money. It was no more in our power to refuse to keep the Institute abreast of the age, in the matter of the fulness and variety of instruction, than it was to reject the hundreds of pupils applying for admission, in excess of our traditional numbers. It was morally necessary that we should at once enlarge the school, and improve it. During the past five or six years, a new and most important scientific profession, that of electrical engineering, has emerged into the field of industry; while, within the more familiar professions, the demand for a higher order of expert work has invited further and still further specialization, requiring the introduction of large groups of optional studies not known to the catalogues of former years.

In this effort to make the Massachusetts Institute of Technology second to none in the world, the Corporation have succeeded, — thanks, largely, to the zeal, learning, and sound judgment of a devoted and self-sacrificing body of professors and instructors; but the funds which are needed to secure that position beyond temporary disaster or business depression, to give the benefits of our instruction to the largest number of deserving pupils, and to yield an adequate remuneration to the instructing staff, have not been placed at the disposal of the Corporation.

I am speaking in no spirit of complaint or censure. The munificence of the citizens of Boston, of Massachusetts, of

New England, in endowing and supporting institutions of art and learning, has long been the admiration of the men of other regions and of other countries. Growing up under the shadow of a university not more honored by time than by fortune, rightfully wearing as her crown-jewels the affection and gratitude of the land to whose prosperity, order, and virtue she has so largely ministered through successive generations, with many another institution of beneficence claiming a share in the public thought, and in the special interest of the wealthy, — it is not surprising that this new school, representing the new education, should still be poor.

Nor is it a subject altogether of regret, that in the past we have been somewhat pinched for means. The early growth of the Institute may not inconceivably have been sounder and firmer, because slow and painful. But I think no one can know much of this school without having a strong conviction that the full time has now come, when it requires for its greatest usefulness, for the maintenance of its high character among the scientific institutions of the world, and for its security against disaster and business depression, large, very large, additions to its permanent investments.

We should have half a million of dollars for immediate, imperative needs; it would require a million to place us in as good a financial condition as the poorest school of our rank in the United States. This is not, it should be borne in mind, an appeal in behalf of an institution whose necessities arise from its failing to meet a public demand; which is to be supported because it was once brought into existence, and is to be kept alive, whether wanted or not, by pleas *ad misericordiam.* The urgent necessities of the Massachusetts Institute of Technology have arisen through the growing popular appreciation of the kind of education which is here given, through the very success of our graduates in dealing with the problems of practical life. The needs of the Institute are so great, because the Institute

is itself so much needed. It will not be like Massachusetts, if those wants are not, in a near future, fully and liberally supplied.

Gentlemen of the Corporation, — the same year which has witnessed, not only the first, but also the second death among the corps of instructors of the Massachusetts Institute of Technology, has seen the hand of the Destroyer laid more heavily than ever before upon our own body. Your minds have already recalled the names and faces of the four members of the Corporation who have passed away from earth since the December meeting of 1885.

In Mr. John C. Hoadley, we have lost one of the foremost engineers of this country of great engineers, — a scholar, also, in the higher walks of literature; in the Rev. Dr. Lothrop, a devoted friend of this institution, one who, to an unusual degree, mingled with the virtues of his sacred calling the shrewd wit and practical sense of a man of the world; in Dr. John D. Philbrick, a master of educational science; in Mr. Henry P. Kidder, one of Boston's noblest citizens, who, in his lofty career, did not more to promote the financial greatness of his city and his State, than to advance their intellectual and moral purity and prosperity, who won great wealth by honorable means that he might devote it to beneficent uses, who never saw the sun set upon a day in which he had not done good to others, and who, through all his life, unconsciously builded his own monument, compact of worthy deeds. In filling the places thus left vacant, we shall search widely and choose carefully; but we cannot hope altogether to make good these losses, for four such men will come to us, at the best, not in a year, but in a decade.

FRANCIS A. WALKER, *President.*

43

Mass. Institute of Technology.

President's Report,

Dec. 14, 1887.

BOSTON:
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1888.

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To the Corporation of the Massachusetts Institute of Technology:

THE experiences of the Institute of Technology during the past twelve months, and the general course of events, as affecting the school, have been altogether favorable and fortunate.

The class of 1887 graduated on the 31st of May. Of the 61 students of the fourth year, who were candidates for the degree of Bachelor of Science, 58 were admitted to that grade by your authority, upon the recommendation of the Faculty of the School of Industrial Science.

The class thus graduating consisted, without exception, of good students, well qualified and well disposed to do honor to the institution which trained them. Their entrance into the several industrial professions has been easy and rapid. The applications for students in all the technical courses equaled, and in some courses largely exceeded, the number graduating. In either chemistry or civil engineering it would have been practicable to place twice as many men as were available in eligible professional positions, between the close of the past and the opening of the present year. So great was the demand for members of the graduating class, that it was for the first time found impracticable to fill all the vacant assistantships, in the several laboratories, from our own numbers, and we were obliged in two cases to send to other institutions for men to take these positions, and, in a third case, to appoint one of our special students, not a graduate.

THE NEW YEAR.

The opening of the school year, 1887–88, witnessed large additions to the number of our students. The register of all the departments and schools under the control of the corporation shows an aggregate of 819 against 738 last year.

Omitting from consideration, as is usual, the students of the Lowell School of Practical Design, and the students of the High School of Mechanic Arts, we find the number in the School of Industrial Science to be 720, against 637 last year, showing an increase of 83, or thirteen per cent.

The following table exhibits the number of students in the School of Industrial Science each year, from the opening of the Institute to the present time:

Year.	No. of Students.	Year.	No. of Students.
1865–66	72	1877–78	194
1866–67	137	1878–79	188
1867–68	167	1879–80	203
1868–69	172	1880–81	253
1869–70	206	1881–82	302
1870–71	224	1882–83	368
1871–72	261	1883–84	443
1872–73	348	1884–85	579
1873–74	276	1885–86	609
1874–75	248	1886–87	637
1875–76	255	1887–88	720
1876–77	215		

Had the remarkable increase in the number of students since 1878 been secured by any lowering of the standard of scholarship, any surrender of the requirements for admission, for continuance in the school, or for graduation from it, that increase of numbers would not be to me a subject of pride or pleasure; but when I consider that this increase, to nearly four-fold the number, nine years ago, has taken place coincidently with a steady advance in scholarship; that these great bodies

of students have come to us well knowing that the Institute is a place for hard study, and cheerfully accepting the conditions which we impose: this, I confess, appears to me a proper subject for congratulation. Not only so, but this readiness and eagerness on the part of so many young men to undertake severe and protracted courses of study, regarding which there can be no pleasing illusions, and which require the entire devotion of time and thought and strength for four years, affords a most gratifying indication of the essential manliness of young men.

Our experience, at least, furnishes no support to the view that, in order to make a school popular, the requirements for admission or continuance must be placed low, or, if the theoretical standard be high, administrative concessions must be freely made to the spirit of indolence or frivolity, or to the demands of sport or of society. Not only is it true that students, in increasing numbers, come to the Institute in spite of its reputation for hard work, but it is not less conspicuously true that, within the Institute, the students, by a very decided preference, select those courses which are recognized as involving the greatest amount of study and practice. It is, also, true that, within the several courses, those options which offer the largest capabilities are those most generally chosen.

The aggregate for 1887–88 is divided among the several classes as follows:

Graduate student, candidate for an advanced degree	1
Regular students, Fourth Year	80
" " Third Year	78
" " Second Year	124
" " First Year	237
Special students	200

Assigning the special students to classes according to the predominant studies pursued by them, we reach the following statement of the division of the whole body among the several years:

Class.	Regular.	Special.	Total.
Graduates of the M. I. T. . .	1	1	2
Fourth Year	80	20	100
Third Year	78	42	120
Second Year	124	71	195
First Year	237	66	303
	520	200	720

STATISTICS OF EXAMINATIONS.

The results of the applications for admission to all classes of the School of Industrial Science thus far in the current school year, and of the examinations had thereupon, may be stated as follows:

Forty-nine were admitted without examination, either to the first-year class, upon presenting certificates of clear admission to some college of reputable standing, or, upon the presentation of diplomas of graduation from some degree-conferring institution, classical or scientific, to our second or third-year class as regular students, or to some department as special students; 199 were admitted upon examination, free of conditions; 61 were admitted with one condition imposed, 27 with two conditions, 11 with three conditions, 3 with four conditions; 36 applicants were rejected upon examination; 15 were admitted as special students, upon examination in the studies specially requisite to the partial courses which they proposed to follow.

The total number of applicants appears, therefore, to have been 401. Of those admitted upon examination, 41 have not thus far entered the school. In some instances, in the case of applicants heavily conditioned, this has been due to the advice of the Faculty that a longer period be taken for preparation; in some, to a change of plans, to sickness, or other causes.

EXAMINATIONS AT DISTANT POINTS.

In addition to the entrance examinations held in Bos-

ton in June and September, 1887, examinations were also conducted in June at Atlanta, Chicago, Cincinnati, Montreal, Nashville, New York, Philadelphia, Pittsburgh, San Francisco, St. Louis, St. Paul, and Washington.

STATISTICS OF RESIDENCE.

Twenty-seven States of the Union, besides the Territories of Dakota and Washington and the District of Columbia, are represented on our lists of students. Canada, Ireland, Peru, Brazil, Guatemala, Turkey, the West Indies, and Japan have also sent us students.

Of the total number of 720, including special students, 429 are from Massachusetts, or 59.6 per cent of the whole; 98 are from other New England States; 193 from outside New England.

The following table shows the number of students of each specified class, from each State or foreign country:

State.	Candidates for Advanced Degrees.	Fourth Year.	Third Year.	Second Year.	First Year.	All Regular Students.	Special Students.	Total.
Arkansas	..	..	..	1	1	2	1	3
California	..	1	2	2	1	6	3	9
Colorado	..	..	..	..	2	2	..	2
Connecticut	..	2	..	3	15	20	9	29
Dakota	..	..	..	1	..	1	..	1
Dist. Columbia	..	..	..	..	4	4	..	4
Georgia	..	..	..	..	1	1	1	2
Illinois	..	1	1	6	14	22	7	29
Iowa	..	..	1	1	...	2	1	3
Kentucky	..	..	..	1	1	2	..	2
Maine	..	1	2	2	10	15	9	24
Maryland	..	1	..	1	...	2	..	2
Massachusetts	..	59	60	75	138	332	97	429
Michigan	..	1	1	1	2	5	5	10
Minnesota	..	2	..	2	1	5	1	6
Missouri	..	..	..	..	2	2	3	5
Nebraska	..	..	1	..	1	2	2	4
New Hampshire	..	2	3	2	3	10	9	19
New Jersey	..	..	..	2	1	3	8	11
New York	..	2	2	4	13	21	14	35
Ohio	..	2	1	5	5	13	8	21
Pennsylvania	1	..	1	2	5	9	9	18
Rhode Island	..	3	2	6	3	14	5	19
South Carolina	..	..	..	..	..	..	1	1
Tennessee	..	..	..	..	1	1	1	2
Texas	..	..	..	..	..	..	1	1
Vermont	..	..	..	2	3	5	2	7
Virginia	..	1	1	1	1	4	1	5
Washington Ter	..	..	..	..	1	1	..	1
Wisconsin	..	1	..	2	..	3	2	5
Foreign Country.								
Brazil	..	..	..	..	1	1	..	1
Guatemala	..	..	..	..	1	1	..	1
Ireland	..	..	..	..	1	1	..	1
Japan	..	1	..	..	..	1	..	1
Peru	..	..	..	1	..	1	..	1
Porto Rico	..	..	..	..	1	1	..	1
Prov. of Ontario	..	..	..	1	..	1	..	1
Prov. of Quebec	..	..	..	..	2	2	..	2
Trinidad	..	..	..	..	1	1	..	1
Turkey	..	..	..	..	1	1	..	1
	1	80	78	124	237	520	200	720

RESIDENCE OF MASSACHUSETTS STUDENTS.

It has been said that 59.6 per cent of all our students are from Massachusetts. All the counties of the State, except the small county of Dukes and Nantucket, send students to the Institute of Technology. Ninety-six cities and towns are reported on the lists. The first column of the following table shows the number of cities and towns in each county sending pupils to the Institute; the second column gives the aggregate number from each county. It appears that Suffolk furnishes us 161 pupils; Middlesex comes next, with 116; Essex third, with 40; Norfolk fourth, with 39:

County.	No. of Towns.	No. of Students.	County.	No. of Towns.	No of Students.
Barnstable .	4	4	Hampden . .	4	9
Berkshire . .	2	3	Middlesex . .	26	116
Bristol . . .	5	21	Norfolk . . .	11	39
Essex . . .	19	40	Plymouth . .	11	17
Franklin . .	1	2	Suffolk . . .	3	161
Hampshire .	2	3	Worcester . .	8	14
			Total . .	96	429

The following is a list of the towns, twenty-five in number, which send four or more scholars to the Institute:

Boston 152	Lynn 7	Taunton 5
Newton 27	Melrose 7	Concord 4
Brookline . . . 13	New Bedford . . 7	Holyoke 4
Cambridge . . . 12	Salem 7	Milton 4
Lowell 11	Malden 6	Plymouth . . . 4
Chelsea 8	Somerville . . . 6	Stoughton . . . 4
Lawrence . . . 8	Winchester . . . 6	Watertown . . . 4
Fall River . . . 7	Framingham . . 5	Worcester . . . 4
Hyde Park . . . 7		

PROPORTION OF OLD AND OF NEW STUDENTS.

The following table exhibits, for each year of the school's history, the distribution of the total number of students among two classes; first, those students whose names are found upon the catalogue of the year preceding; and secondly, those students whose names appear as new names upon the catalogue of the year to which the statement relates:

Year.	(1) Total No. of Students.	(2) No. of Students in the Catalogue of the previous year who remain in the Institute.	(3) No. of New Students entering before issue of Catalogue.	(4) Of those in column (3) the following number are regular first-year Students.	(5) No. of New Students not of the regular first-year class.
1866–67	137	34	103	58	45
1867–68	167	79	88	54	34
1868–69	172	82	90	50	40
1869–70	206	90	116	63	53
1870–71	224	109	115	71	44
1871–72	261	122	139	82	57
1872–73	348	173	175	112	63
1873–74	276	171	105	59	46
1874–75	248	159	89	35	54
1875–76	255	139	116	65	51
1876–77	215	130	85	31	54
1877–78	194	96	98	47	51
1878–79	188	99	89	34	55
1879–80	203	102	101	34	67
1880–81	253	121	132	62	70
1881–82	302	136	166	86	80
1882–83	368	173	195	114	81
1883–84	443	231	212	140	72
1884–85	579	311	268	186	82
1885–86	609	369	240	177	63
1886–87	637	379	258	190	68
1887–88	720	396	324	229*	95

It appears from the foregoing that the number of students remaining over has been increased by 17, while the number registered for the first time is larger by 66; making the net gain, as previously stated, 83.

* In addition, 8 students are repeating the first year.

AGES OF STUDENTS ON ENTRANCE.

The next table exhibits the ages of our students upon entrance. The regular students of the first-year class number 237. From these we should except nine cases of students of unusual ages; viz., five of 22, one of 24, two of 25, and one of 30 years. These deductions leave 228 as the number of students whose ages have been made the subject of computation.

The results appear in the following table, in comparison with the corresponding results for 1886–87:

Period of Life.	1886–87.		1887–88.	
	Half-Year Groups.	Yearly Groups.	Half-Year Groups.	Yearly Groups.
16 to 16½ years	10		3	
16½ to 17 years	19	29	13	16
17 to 17½ years	16		34	
17½ to 18 years	33	49	41	75
18 to 18½ years	38		42	
18½ to 19 years	23	61	28	70
19 to 19½ years	21		30	
19½ to 20 years	15	36	16	46
20 to 20½ years	9		12	
20½ to 21 years	6	15	4	16
21 to 22 years	5	5	5	5
	195	195	228	228

From the foregoing tables it appears that the average age of the 228 students taken for this comparison, the present year, is 221.55 months, or 18 years, 5 months, and 17 days. This compares with the corresponding figures relating to the two previous entering classes, as follows:

	Av. Age in Months.
Class of 1889	218.53
Class of 1890	219.91
Class of 1891	221.55

The progressive enhancement of the age of students upon entrance must be regarded as a proper subject of con-

gratulation, when consideration is had of the nature of the work at the Institute, and the immediate entrance which it affords into professional practice.

It is true that the postponement of the age of entrance has of late caused some apprehension on the part of those who direct the classical colleges of New England, and that serious consideration has been given to various proposed means of meeting this tendency; but their problem is not our problem. In the case of students graduating from classical colleges, there is generally to follow a course of two or three years in professional schools, whether of law, of medicine, or of divinity, which is, in turn, to be followed by a longer or shorter period — sometimes a long and weary one — of waiting for professional practice. Under these circumstances, it is undoubtedly a hardship that the age of graduation with the Bachelor's degree should be postponed beyond the 21st, much more, beyond the 22d, year of life. It is unquestionably true that a young man who commences the full, busy practice of his profession before he is 25 years of age has an advantage over one commencing at a later period, in the matter of freshness, spontaneity, hopefulness, and enthusiasm.

In our case the relations of instruction to professional practice are altogether different. A young man who has pursued one of our courses with credit may, if he pleases, enter into the practice of his profession the day after he graduates, often with a choice among several positions offered him. In these circumstances graduation at 22 years must be regarded as more fortunate than graduation at an earlier period; while 23 or 24 years cannot be considered as in any sense excessive.

In this connection it may be interesting to note the ages at graduation of the class leaving us in May. Of the 58 members of the class the age of one is not known; the remaining 57 were distributed among several periods of life, as follows:

Under 20	1	Between 22 and 23	7
Between 20 and 20½	2	" 23 and 24	7
" 20½ and 21	7	" 24 and over	7
" 21 and 21½	11		57
" 21½ and 22	15		

PROPORTION OF REGULAR AND OF SPECIAL STUDENTS.

The following table exhibits both the absolute number of regular and of special students, as by the catalogue of each successive year, and the proportion existing between these two classes:

Year.	No. of Regular Students.	No. of Special Students.	Total No. of Students.	Percentage.	
				Regular.	Special.
				Per cent.	Per cent.
1865–66	64	8	72	89	11
1866–67	110	27	137	80	20
1867–68	124	43	167	74	26
1868–69	105	67	172	61	39
1869–70	125	81	206	71	29
1870–71	143	81	224	64	36
1871–72	180	81	261	69	31
1872–73	235	113	348	68	32
1873–74	182	94	276	66	34
1874–75	170	78	248	69	31
1875–76	182	73	255	71	29
1876–77	134	81	215	62	38
1877–78	117	77	194	60	40
1878–79	103	85	188	55	45
1879–80	110	93	203	54	46
1880–81	140	113	253	55	45
1881–82	164	138	302	54	46
1882–83	219	149	368	60	40
1883–84	272	171	443	61	39
1884–85	368	211	579	64	36
1885–86	415	194	609	68	32
1886–87	442	195	637	69	31
1887–88	520	200	720	72	28

It will be seen that the tendency previously noted towards a progressive increase in the proportion of students taking the full regular course, still continues. The policy of the Institute regarding special students was very fully presented in the annual report for 1885.

WOMEN AS STUDENTS IN THE INSTITUTE.

The number of young women attending the Institute of Technology is never likely to be large, considering the nature of the professions to which our courses lead, and the severity of our requirements for admission and for graduation. At the same time the laboratories and class-rooms of the Institute are freely open to all women who think to find here opportunities for scientific study and experiment which are not afforded in schools for their own sex exclusively.

The number of women pursuing courses with us the present year is 25, of whom 4 are graduates of colleges. Of the total number 2 are regular students of the fourth year; 2 regular students of the second year; 3 regular students of the first year; 18 are special students. Of the four regular students of the upper classes, one takes Course IV, architecture; one Course VIII, physics; two Course IX, the general course; of the special students, 13 devote themselves chiefly to chemistry and physics; 4 chiefly to biology and allied subjects; 1 to the modern languages.

GRADUATES OF OTHER COLLEGES.

Twenty-three graduates of institutions conferring degrees are included in our list of students for the present year. Of these, two are our own graduates, one of whom is pursuing advanced studies as a candidate for the degree of Doctor of Philosophy. Twenty-one are graduates of other institutions, either scientific or classical, pursuing courses of study with us, either as regular students, candidates for our Bachelor's degree, or as special students. Of these, five are graduates of Harvard University, two each of Brown University, Yale University, and Colby University, while one comes from each of the following institutions: the University of the Pacific, Beloit College, Ohio State University, Boston University, Vassar College, University

of Minnesota, University of Wisconsin, Oberlin College, Haverford College, and the New Hampshire College of Agriculture.

Of the twenty-one, four are regular students of the fourth year, one each in mechanical engineering, in electrical engineering, in physics, and in general studies; one is a regular student in civil engineering, in the third year; two are regular students in mechanical engineering, and one in architecture, in the second year; one is a regular student in the first year. The remaining fourteen are special students.

THE COURSES OF INSTRUCTION.

The present fourth-year class comprises one or more candidates for the Bachelor's degree in each department of the Institute.

The following table presents the number of students in each of the regular courses. It will be seen that this statement relates to the second, third, and fourth years, choice of courses being made only at the end of the first year:

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Electrical Engineering.	Natural History.	Physics.	General Course.	Total.
4th Year Class . . .	10	27	5	5	9	19	3	1	1	80
3d " " . . .	17	20	4	5	8	20	–	2	2	78
2d " " . . .	23	42	7	8	6	22	2	3	11	124
Total	50	89	16	18	23	61	5	6	14	282

Not only do all the nine courses contain candidates for the degree of the Institute, in the fourth-year class, but these are fairly well distributed among the various branches of the several courses. Thus, in Course I, of the ten students, five follow the traditional line of instruction in civil

engineering, while five have taken railroad engineering. There are no students of the fourth year taking the option in geodesy and geology.

In Course II, of the twenty-seven students of the fourth-year class, four are taking the marine engineering option; six, the locomotive engineering option; seventeen, the mill engineering option.

In Course III, of the five students of the fourth year, three are following the mining branch; two, the metallurgical.

In Course VII, of the three students of the fourth year, one is taking the full line of study and practice in natural history, while two are pursuing biology preparatory to medical studies.

The other courses are not divided into distinct branches, although in several of them extensive options are offered to the student. Speaking broadly, the optional studies of successive years, within any course, are so related to each other that the student, pursuing one or another "Option," acquires thereby a professional specialty, in addition to his general training and preparation for his profession.

The following table exhibits the number of persons who have graduated within each of the several courses, at each succeeding year since the first diplomas were conferred in 1868. In this table the term "General Courses" will be understood to embrace alike the "Science and Literature" Course of the period 1868–1880, and the Elective and General Courses of the period subsequent:

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering.	Architecture.	Chemistry.	Metallurgy.	Electrical Engineering.	Natural History.	Physics.	General Courses.	Total.
1868	6	1	6	..	..	..	..	..	..	1	14
1869	2	2	..	..	1	..	..	..	..	..	5
1870	4	2	2	..	1	..	..	..	..	1	10
1871	8	2	5	..		..	..	..	..	..	17
1872	3	1	5	..	3	..	..	..	..	..	12
1873	12	2	3	1	7	..	..	..	..	1	26
1874	10	4	1	1	..	..	..	..	..	2	18
1875	10	6	6	1	1	..	..	..	1	2	27
1876	12	9	7	..	5	1	..	2	3	4	43
1877	12	6	8	4	2	..	..	..	..	..	32
1878	8	2	2	3	3	..	..	..	..	1	19
1879	6	8	3	1	3	..	..	1	1	..	23
1880	3	..	3	..	1	..	..	..	..	1	8
1881	3	5	6	3	8	..	..	1	..	2	28
1882	2	5	5	3	6	..	..	1	1	1	24
1883	3	7	4	1	3	..	..	..	..	..	18
1884	5	6	13	..	12	..	..	..	..	..	36
1885	4	6	8	2	4	..	2	..	..	1	27
1886	9	23	7	1	7	..	10	1	..	1	59
1887	10	17	8	1	9	..	8	1	1	3	58
Total	132	114	102	22	78	1	20	7	7	21	504
Deduct names counted twice											2
											502

THE WORK OF SPECIAL STUDENTS.

The 200 special students in the School of Industrial Science cannot be classified systematically; but the following table exhibits the number of special students pursuing each particular branch of study, according to the attendance papers filed by them and approved by the Faculty:

NUMBER OF SPECIAL STUDENTS ATTENDING EXERCISES IN THE FOLLOWING DEPARTMENTS OF STUDY OR PRACTICE.

Architecture	49	Geology, etc.	37
Applied Mechanics	25	German	76
Chemistry	80	Mathematics	85
Civil Engineering	29	Mechanical Engineering	31
Mechanical Drawing	34	Mining and Metallurgy	23
Descriptive Geometry	22	Physics	80
English	60	Shopwork	40
French	43	Heating and Ventilation	13

Total number of entries, by special students	727
Total number of special students	200
Average number of entries	3.6

It may be of interest to note the numbers of students, either regular or special, pursuing certain leading branches of study, in each of the four years, which are as follows:

	First Year.	Second Year.	Third Year.	Fourth Year.	Total.
Mathematics	263	146	85	69	563
Chemistry	282	40	28	23	373
English	244	151	64	3	462
French	231	17	8	8	264
Physics	..	167	94	30	291
German	26	156	104	6	292
Shopwork *	..	91	29	36	156

THE CORPS OF INSTRUCTORS.

A still further increase of the instructing staff has been required during the year.

The number of instructors of all grades, excluding those persons who are announced as lecturers for the year only, is 75, against 69 last year.

The number of professors in the school is now 13; of associate professors, 6; of assistant professors, 9; of instructors, 30; of assistants, 17.

* Exclusive of students in the School of Mechanic Arts.

The following table shows the number of teachers of each recognized grade in each year since the foundation of the school:

Year.	Professors.	Associate Professors.	Assistant Professors.	Instructors.	Assistants.	Total.
1865–66	10	..	..	..	..	10
1866–67	12	..	..	2	..	14
1867–68	12	..	1	2	2	17
1868–69	13	..	..	6	1	20
1869–70	16	..	1	6	2	25
1870–71	18	..	2	7	5	32
1871–72	21	..	2	11	1	35
1872–73	23	..	2	9	1	35
1873–74	20	..	3	10	4	37
1874–75	20	..	3	7	3	33
1875–76	23	..	..	6	8	37
1876–77	21	..	..	4	10	35
1877–78	20	..	..	3	14	37
1878–79	18	..	..	7	12	37
1879–80	16	..	..	7	8	31
1880–81	15	..	2	6	7	30
1881–82	17	..	3	6	11	37
1882–83	16	..	3	10	11	40
1883–84	15	..	8	15	10	48
1884–85	14	3	11	15	14	57
1885–86	14	6	7	17	18	62
1886–87	12	7	6	27	17	69
1887–88*	13	6	9	30	17	75

The changes of the year affecting the list of instructors have been numerous. Associate Professor George F. Swain has been appointed Hayward Professor of civil engineering, and placed in permanent charge of that important and growing department of the Institute. During the year Professor Swain's professional accomplishments have received most honorable recognition in his appointment, under a law of the last Legislature of Massachusetts, as Engineer to the Board of Railroad Commissioners, charged with conducting an examination of all railroad bridges within the limits of the Commonwealth.

* In addition there are 3 instructors and 4 assistants in the School of Mechanic Arts.

Mr. Charles D. Jameson, owing to ill health, was obliged to resign his position as instructor in railroad engineering. I am happy to add that Mr. Jameson has since so far recovered his health as to enable him to accept the professorship of engineering in one of the important institutions of the West.

The vacancy created by Mr. Jameson's withdrawal from the Institute of Technology was filled by the appointment of Mr. C. Frank Allen, as assistant professor of railroad engineering. Professor Allen graduated from the Institute in the class of 1872. From that time until 1879 he was engaged upon works of water supply and sewerage, in Providence and in the vicinity of Boston. During that period Mr. Allen was active in the organization of the Institute Alumni Association, and in engaging the aid of the alumni in support of the school, then in its lowest state of depression. In 1879 Mr. Allen went West and entered the service of the Atchison, Topeka, and Santa Fé Railway, where, with an interval of service on the Mexican Central road, he remained until called to his present position. His experiences during the past ten years have embraced almost every branch of railroad work and have eminently fitted him for his present duties.

Another appointment to the Faculty, during the year, has been made within the same department, Mr. Dwight Porter having been appointed assistant professor of civil engineering. Professor Porter graduated from the Sheffield Scientific School, of Yale College, in the class of 1880, with high honors. He immediately entered the employ of the government, as an expert special agent of the tenth census, and for about three years was engaged in a hydrographic reconnoissance of various portions of the United States. His reports on water power employed in manufactures, as contained in Volume 16 of the census, exhibit marked abilities and thorough scientific training. In 1883 Mr. Porter was appointed instructor in drawing and mathematics in

this school, and in 1884 instructor in civil engineering. As an important part of his duties, Professor Porter has charge of the instruction in sanitary engineering.

In the department of mining engineering and metallurgy, Mr. Frederick W. Clark has been appointed assistant professor. Professor Clark graduated in the class of 1880; and, after about two years and a half of professional practice in the mining districts of Idaho and Colorado, returned to the Institute as an instructor, in which capacity he has served with marked success, besides greatly aiding Professor Richards in the extension and development of the mining and metallurgical laboratories.

In the department of architecture, Mr. Thomas O'Grady having withdrawn from the position of instructor, Mr. Eleazer B. Homer has been appointed in his place. Mr. Homer graduated from the Institute in the class of 1885, and has since that time and up to the date of his appointment been engaged in professional work in the office of Messrs. Hartwell & Richardson, Boston. That department has been still further reinforced, to meet the demands of an increasing number of students, by the appointment, as junior instructor, of Mr. Dwight H. Perkins, who completed the two years' partial course in architecture at the Institute, with marked success, in May last.

In the department of chemistry Professor Pope has continued to give the lectures to the first-year class in general chemistry, formerly given by Professor Nichols. Mr. Howard V. Frost still remaining abroad, in further pursuit of his chemical studies, the charge of the laboratory of general chemistry has devolved upon Mr. Frederick L. Bardwell, who has shown great energy and good judgment in the conduct of this large and difficult department. Mr. Augustus H. Gill, instructor in general chemistry, after a valued service of three years, resigned to enter the employ of the State Board of Health, in connection with the system of water analysis, which will be spoken of hereafter. Mr.

Peter Burns, a graduate of Iowa Agricultural College, one of the assistants of last year, has been appointed instructor in Mr. Gill's place. In the laboratory of analytical chemistry the teaching staff has been strengthened by the appointment of Mr. Henry P. Talbot, of the class of 1885, as instructor, after two years' experience as an assistant.

In the department of physics, Mr. W. H. Pickering having resigned, as will be hereafter more fully explained, Mr. William L. Puffer, of the class of 1884, has been appointed instructor, after three years' service as an assistant.

In the department of mechanical engineering Mr. Allyne L. Merrill, of the class of 1885, has been appointed instructor, after two years' service as an assistant, to fill the vacancy caused by the resignation of Mr. Alfred L. Fitch, after three years of valued service in that laboratory. The mechanical engineering laboratory has been strengthened by the appointment of an additional assistant.

Mr. H. W. Tyler, of the department of mathematics, has, during the year, gone abroad, under a two years' leave of absence, to further pursue his mathematical studies.

The increase in the numbers of the first and second-year classes has required an addition to the instructing staff in the department of modern languages. Mr. Eugene H. Babbitt has been appointed to the position of instructor. Mr. Babbitt was graduated from the Connecticut State Normal School in 1880 and from Harvard in 1886, with highest honors in Modern Literature. He spent the year 1886–7 in Berlin and Paris, and has already achieved marked success as a teacher, both before entering Harvard and during his senior year there. The instruction in English has been further strengthened by the appointment of an assistant in this department.

Instruction in Spanish is given by Mr. John F. Machado of Salem, an accomplished scholar, to whom Spanish is his native tongue.

Dr. Edward G. Gardiner, during the past three years

assistant in the biological laboratory, has been appointed instructor in biology. Mr. Charles W. Eaton, for three years assistant in drawing, has been appointed an instructor.

The assistants for the school year, 1887–88, are as follows: Dana P. Bartlett and George W. Patterson, Jr., in mathematics; Fred P. Emery (A. B., Dartmouth), in English and history; John M. Fox, in drawing; Arthur G. Robbins, in civil engineering; Edward F. Miller, Ralph E. Curtis, and William O. Hildreth, in mechanical engineering; Timothy W. Sprague, in mining and metallurgy; Edward S. Foss, Charles B. Kendall, and Joseph P. Grabfield, in general chemistry; Frederick Fox, in sanitary chemistry; Arthur A. Noyes and Alfred J. Wakeman, in chemical analysis; Harry E. H. Clifford and Walter S. Moody, in physics.

In addition to the regular staff of instruction the following gentlemen have been appointed lecturers for the current year: George W. Blodgett, S.B., on applications of electricity to railway working; Henry M. Howe, A.M., S.B., on metallurgy; C. Howard Walker, on history of ornament; Ross Turner, on water color and sketching; Charles W. Hinman, S.B., on the manufacture of illuminating gas; Walter S. Allen, S.B., on the manufacture of fertilizers; Eliot Holbrook, S.B., on railroad maintenance; Charles E. Mills, in charge of life class; David A. Gregg, on fine art; David L. Barnes, on locomotive construction; Anthony C. White, S.B., on the distribution of electricity for commercial purposes; Edward Blake, Ph.B., on the construction and applications of electro-motors.

The following table exhibits the number of instructors of all classes, including the lecturers appointed for the current year, assistants performing the duties of instructors, assistants in drawing rooms and laboratories, and also instructors and assistants in the mechanic arts:

	Civil Engineering.	Mechanical Eng. and App. Mechanics.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Physics and Elect. Engineering.	Biology, Zoölogy, etc.	Mineralogy, Geology and Geography.	English and Political Science.	Language.	Mathematics.	Drawing and Descrip. Geometry.	Mechanic Arts.	Military Tactics.
Professors.....(13)	1	1	1	1	1	1	1	1	2	1	2	....	....	....
Associate Professors (6)	....	....	....	1	1	1	1	....	...	1	1	....	....	....
Assistant Professors (9)	3	2	1	....	1	....	....	1	....	....	....	1	....	....
Instructors.....(33)	....	4	....	2	7	3	1	1	2	3	3	3	3	1
Assistants.....(21)	1	3	1	....	6	2	....	...	1	....	2	2	3	....
Total.....(82)	5	10	3	4	16	7	3	3	5	5	8	6	6	1
Lecturers .....(12)	1	1	1	4	2	3	....	....	....	....	....	...	....	...
Total..... (94)	6	11	4	8	18	10	3	3	5	5	8	6	6	1

CHANGES IN COURSES OF STUDY AND IN LABORATORY ACCOMMODATIONS.

In the report of last year the introduction of certain extensive "options" into the civil engineering course was mentioned. The option in railroad engineering has already proved attractive to a considerable proportion of the students of the department. No important change from the projected scheme has been found necessary.

The option in geodesy and geology, instituted for the first time last year, has this year been put into definite form, and a complete scheme of study, down to the end of the fourth year, has been adopted by the Faculty. The course, as arranged, provides for very extended instruction in geodesy and topography, as well as in the geological and mathematical subjects which find their application in the execution of geodetic or geological surveys. Already there are students of the third year taking this option, with a view to graduation in 1889.

In connection with the option in geodesy and geology within the Institute of Technology, and also with a view to supplying a public want which has for a long time been felt, provision has been made for a Summer Course in topography, geodesy, and geology, extending through the early part of the vacation following the close of the third year. Such a summer school will allow of more continuous field practice than it is possible to provide in connection with the exercises of either term. The object in view will not be the accomplishment of a certain piece of topographical or geodetic work, but the instruction of the student, by actual practice in the field, in the methods of carrying on geological or geodetic surveys. A base line will be measured, and the methods of extending the triangulation and of filling in the details will be fully explained and exemplified. Field geology will also constitute an important feature of this course. The instruction will be given by members of the teaching staff of the Institute. The school will be established in some favorable location in the State of Massachusetts, presumably in the Connecticut Valley; and the work will be, as far as possible, connected with that of the Massachusetts State survey, now approaching its completion.

Attendance upon the summer school of geodesy and geology will be obligatory upon all students in the civil engineering department who take the option in geodesy and geology; and the school will be open, without extra charge for tuition, to all properly qualified students of the Institute. Students from without the Institute will be admitted upon their exhibiting the proper qualification and upon the payment of a moderate tuition fee. A circular is now in course of preparation which will present, for public information, a full account of the civil engineering department in all its branches, after the changes made during the past and the present year. The work in this department is being more and more turned in the direction of original

research. Among the theses of last year were two which deserve to be ranked as real additions to our knowledge of the subjects of which they treat. The results of one of them — a laborious and extended investigation into the changes of dimension of American cements during induration, by Messrs. W. C. Cushing and W. S. Thompson — were last summer presented to the American Society of Civil Engineers, and will be published in the transactions of the society. The other — an investigation of the flow of water over submerged weirs, by Mr. J. W. Smith — will be published at an early date.

Owing to the increase in the number of students in this department, it was found necessary to increase the amount of space allotted to it; and the department accordingly relinquished room 23 to the teachers in architecture, and itself took possession of room 14 — the large hall on the first floor of the new building. The surrender to a single department of this room — heretofore used for lectures, public gatherings, etc. — is a matter of regret, though rendered unavoidable by the demands of present instruction. We can only hope that, in some not distant future, the acquisition of other buildings will render it feasible to restore this valuable room to its original use.

In the department of mechanical engineering there have been no essential changes during the year, but only those additions and alterations which are involved in any vigorous and healthy growth. Professor Peabody's notes on thermodynamics and steam engineering, heretofore given to the students in cyclostyle, have been very fully developed, and have been printed for more convenient use. The three options of the fourth year have been allowed more time, and each will receive a certain further development during the present year. The laboratory is in better working order than ever before; and it is believed that, in the variety and scope of the experiments and researches there conducted, it has no superior among the educational

institutions of the world. An investigation which deserves to be singled out from among the work of the past year was that conducted by Mr. F. H. Crane, of the class of 1886, on the degree of accuracy that may be expected from dynamometers. The number of students in this laboratory is already so large as to test its capacity to the utmost.

The course in architecture has been still further amplified and enriched since my report of last year. A small pamphlet giving an account of the instruction in this department has, within a few weeks, been issued for public information. The large increase of students in this department has rendered it necesary to assign it additional space, and accordingly room 23, when relinquished by the department of civil engineering, was made over into a lecture room and a drawing room, for students in architecture.

In the department of chemistry the year has witnessed a greatly needed addition, in the construction of underground vaults for storage on the Clarendon street side of the new building. These vaults have a floor extent of 60 x 35 feet, and are more than 6 feet in the clear; have been constructed with great pains to secure solidity and dryness; and are capable of holding as large an amount of chemical stores and supplies as it will ever be necessary to keep on hand. The space in the new building, thus cleared, will probably be assigned to the department of industrial chemistry, for the greatly needed extension of its laboratories. Above, room 36 in the third story, heretofore used for all branches of sanitary chemistry, has been assigned exclusively to work upon water analysis, under an arrangement with the State Board of Health, now to be mentioned; and room 34, on the same floor, has been fitted up for the analysis of foods. The name of Wm. Ripley Nichols has been permanently affixed to the library of the chemical department, which now contains more than 2,800 volumes and 2,000 pamphlets.

On the first of June of the current year, at the request

of the State Board of Health, the chemical department of the Institute, with the approval of the Executive Committee of the corporation, took charge of a chemical investigation of the water supplies of Massachusetts. The investigation, as laid out by the Board of Health, was of the most comprehensive nature, and liberal arrangements were made to secure its success. Room 36 of the new building was, as stated, assigned to this service, which was placed under the charge of Professor Drown, assisted by Mrs. Richards, with four other graduates of the Institute. This direct and intimate association of the chemical work of the State with the courses of instruction in water analysis, regularly carried on in the Institute of Technology, has proved to be of much value to the department of sanitary chemistry. During the first six months following the inauguration of this service, not less than 1,300 samples of potable waters, representing the water supply of every important city and town in the Commonwealth, were analyzed by Professor Drown and his assistants. In addition to all the salaries requiring to be paid in connection with the service, the State Board of Health makes an allowance of $1,500 annually, for the rent of the laboratory and for the chemicals and apparatus used in the work.

The regular work in all the other chemical laboratories has been carried forward during the year with even more than the success achieved in the past.

In the department of physics, including electrical engineering, the steady and healthy growth alluded to in my last report has continued without abatement. The laboratory and lecture courses already established have been extended, and a new course of lectures and exercises in the electrical testing of dynamo machines, by Mr. William L. Puffer, one of the instructors in the department, has already been begun. A new course on electric motors will be given by Mr. Edward Blake, and one on the distribution

of electricity, by Mr. Anthony C. White, both of whom were formerly students at the Institute.

The retirement of Mr. William H. Pickering, after a valuable service of over six years, as assistant and instructor in the department of physics, to accept a responsible position in the Harvard College Observatory, has rendered it necessary to rearrange the instruction in photography, which he so successfully developed. In view of the great pressure exerted upon the time of the students, it has seemed to be desirable to reduce the amount of instruction in this subject absolutely required of all, while the extent or the variety of instruction open to those individually wishing or needing advanced work in this direction has been in no way diminished.

Several papers from the Rogers Laboratory have been published during the past year, in the proceedings of the American Academy and elsewhere; and a number of others are already completed, so far as the results of investigation are concerned, and only wait to be put into proper form for publication.

Thanks to the liberality of the corporation and to the kindness of appreciative friends, our collection of physical apparatus, while not in any way showy, is of the greatest value for actual work, and, with the material additions that are made each year, will continue to be sufficient even for our large needs. The recent generous gift, from Mr. Thomas A. Edison, of a powerful incandescent dynamo machine, with all its appurtenances, forming a complete plant for electric lighting, gives to the Rogers Laboratory additional and important facilities for study and investigation. The 150 lamps attached to this machine will be used to light the drawing rooms of the departments of mechanical engineering, architecture, and civil engineering.

The number of students in the course in electrical engineering (VI) is steadily increasing, while there are now,

for the first time in the history of the Institute, candidates for the Bachelor's degree in the course in physics (VIII) in all three of the professional years, viz., one in the fourth year, two in the third year, and three in the second year, while one graduated from this course in June, 1887 — a gratifying evidence that the value of the more purely scientific, as distinct from technical, training, given in the school, is coming to be more widely recognized than hitherto.

It is also hoped that, by the beginning of the next school year, the department will be able to offer to the public somewhat definitely laid-out graduate (commonly called post-graduate) courses, having a minimum duration of one and two years, and leading to advanced degrees in electrical engineering. There is little doubt that, if such courses are actually instituted, the facilities thus offered will speedily be made use of by our own graduates and by those of other institutions.

The department of natural history, Course VII, for the first time, contains this year as many as three candidates for the Bachelor's degree in the fourth-year class, of whom two have it in contemplation to pursue medical studies, upon their graduation from the Institute.

The general course (IX) has been further extended and improved during the year, to enable it to perform that part in the work of the Institute which has been assigned to it by the faculty and government. The changes which have been made are all in the direction which had been previously marked out for the development of this course. A considerable number of the students of the second year have already shown their appreciation of the advantages offered upon this side of the school by entering Course IX. A pamphlet descriptive of the studies and exercises of the course was issued during the summer vacation, for the information of the students and of the public.

CONCLUDING REMARKS.

I have more than once, in the course of this report, had occasion to refer to the standard of scholarship maintained at the Institute. Without regard to this it is, in my judgment, impossible for any one, no matter how near at hand, to understand this school; to appreciate what it is, and why it is such, what it is doing, and how that is done.

The main fact regarding the Institute of Technology, that which renders possible such work as is done here, is the predominant character and spirit of its scholars. This is not to deny credit to the Faculty of today or of the preceding time, since, although the nature of the studies and exercises pursued contributes in an important degree to the result, that result could have been attained only through years of patient, careful, persistent, courageous effort on the part of the teachers in raising and maintaining the standard of scholarship; in creating a public sentiment within the school favorable to manly endeavor, repugnant to foppery, extravagance, triviality, and indolence, and even in educating a wide constituency outside the school, so that our pupils come to us, as a rule, prepared to acquit themselves like men, neither expecting nor desiring any other way of life.

In my last annual report it was said that the Institute of Technology required half a million of dollars for immediate and imperative needs, and that it would take a million to place this institution in as good a financial condition as the poorest school of its rank in the United States. During the twelve months that have elapsed something has been done towards supplying the deficiencies so painfully felt.

By the will of the late Richard Perkins of Boston, who died December 6, 1886, the Institute received $100,000. In addition to the relief afforded to the finances of the school by this munificent bequest, it was gratifying to

learn that it was the result of no sudden thought or casual impulse, but was due to a deep interest for many years cherished by Mr. Perkins, in the work of the school. Before he became a confirmed invalid he found great pleasure in visiting the buildings of the Institute, and, without making himself known, observing the students in their drawing rooms and laboratories.

During a confinement of eight years that interest did not fail, but prompted one of the largest and most timely benefactions in the history of the school. By the liberality of Mrs. Perkins, as residuary legatee under her husband's will, the entire sum was paid over as soon as the will had been admitted to probate. Of the amount thus received, the whole is to be maintained as a permanent fund, the income arising from one half to be used in assisting needy and deserving students, the interest arising from the other half to be applied, at the discretion of the corporation, according to the needs of the Institute. In partial recognition of this gift it has been directed that one of the existing professorships shall hereafter be known as the "Richard Perkins professorship of analytical chemistry."

In accordance with a vote of the corporation, passed at our meeting in December a year ago, the corporation, through its officers, presented a petition to the Legislature of the Commonwealth, in January, asking for a grant of $200,000 from the public treasury, in order that the Institute might be placed upon a more assured foundation. The petition recited the successive acts of the Legislature in the establishment and organization of the Institute, as well as the principal facts in the history of the school; and set forth, as strongly as might be, the present needs of the institution and its claims upon the favorable consideration of the Commonwealth.

In support of this petition, the officers and other members of the corporation appeared before the appropriate committees of the Legislature and urged the unconditional

grant of the entire sum named. Deeply to our regret, however, the Legislature appropriated only one half of that amount, *i. e.*, $100,000, of which $50,000 should be payable on the 1st of December, 1887, and the remaining $50,000 on the 1st of December, 1888, the grant being, moreover, coupled with two conditions: First, that $100,000 from other sources should be added to the funds of the Institute prior to the first payment to be made from the treasury; and secondly, that twenty free scholarships should be established and maintained in the Institute, upon terms which will be found in the text of the law appended to this report.

The first condition has been complied with, largely through the devoted and self-sacrificing labors of Mr. William Endicott, Jr.; and on the 30th of last month the President and Treasurer filed with the Auditor of the State the required certificate, to the foregoing effect. The names found upon the list of this subscription are largely the familiar names which have been prominent in every previous effort for the maintenance and enlargement of this school.

The second condition affixed to the State grant is of a more serious character; and it has seemed best to the executive committee and the finance committee not to draw the first installment of the State grant, now due, until an appeal can be made to the Legislature, at the approaching session, to reduce the burden thus laid upon the finances of the institution. The regular fee for tuition in the school is $200. At that rate, twenty scholarships would cost the Institute the sum of $4,000 annually, which is nearly the whole amount which, at current rates of interest, the entire State grant could be expected to yield. It is felt that, considering the contribution to our funds of one million, two hundred thousand dollars by private citizens, the Commonwealth of Massachusetts can afford to do something

more than this for an institution of such wide and increasing usefulness.

It is proposed, therefore, should it meet the approval of the corporation, to ask the Legislature to increase the amount of the authorized grant by the further sum of $100,000. Should this be done, the Institute of Technology will, for the first time, be in a condition to meet its current expenses out of its annual receipts. Such a result would not avoid the necessity for large additional endowments — first, to secure the school against calamity or reverses of fortune; and secondly, to provide for a continuous future enlargement and improvement of its various services and departments, to meet the ever-growing demands for technical instruction; but it would mark a very important epoch in the history of the Institute of Technology, and would bring an unspeakable relief to the officers and teachers who have so long, in penury and straitness of means, held up the standard of scientific instruction here, amid difficulties and discouragements neither small nor few.

The past year has witnessed the decease of three members of this board. Mr. Charles T. Hubbard had been but for a few months a member of the corporation at the time of his death. The Hon. Marshall P. Wilder was the senior member of the board. Not only was his name embraced in the charter of the Institute, but during the years which preceded the legislative sanction of this enterprise, he was of the small company that labored to arouse public attention to the need of scientific education. Col. Wilder approached the subject rather from the side of agriculture and horticulture, for it is apt to be forgotten that, but for the interposition of the national government in the act of 1862, this institution would have undertaken to promote the agriculture equally with the manufactures of Massachusetts and New England; but his interest in the school did not fail when it was turned from the direction of his own

especial pursuits. During all the remainder of his life, to the long-protracted end, he continued one of the most punctual and attentive members of the board.

It is difficult to find fitting terms in which to speak of the services to the Institute of Mr. Henry B. Rogers. A member of the corporation in the first year of the school, a member of the committee on the school and afterwards of the executive committee, he remained to the last among the wisest of its counsellors, the bravest and firmest of its supporters in every time of doubt and difficulty, the most generous of its benefactors, whether in his own spontaneous and even secret gifts, or through the contributions which his high character enabled him so effectively to solicit from others. A man of antique virtue, inflexible in his integrity and scrupulously opposed to artifice or indirection, yet thoroughly practical, tolerant, and amenable to all considerations of honorable expediency; a man who held his means, his time, his very life in trust for his fellow-men, — Mr. Rogers exemplified a type of citizenship which, we are proud to believe, is more prominent in the civil life of Boston than in that of any other city of the world.

Resolved, That there be allowed and paid out of the treasury of the commonwealth the sum of one hundred thousand dollars to the corporation of the Massachusetts Institute of Technology, in the manner following: An installment of fifty thousand dollars on the first day of December in the present year, and a final installment of fifty thousand dollars on the first day of December in the year eighteen hundred and eighty-eight; said sums to be applied to the purposes of the Institute. And in consideration of this grant said Institute shall establish and maintain twenty free scholarships, and each senatorial district in this commonwealth shall once in eight years, in such alternate order as the Board of Education shall at the time of the first apportionment of said scholarships determine by lot, be entitled to one scholarship for a period of four years, to be awarded to such candidates as shall be found upon examination to possess the qualifications fixed for the admission of students to said Institute, and who shall be selected by the Board of Education; preference in the award being given to qualified candidates otherwise unable to bear the expense of tuition. In case no candidate appears from a senatorial district, then a candidate may be selected from the State at large to fill such vacancy, who may continue to hold the scholarship annually until a candidate is presented from the senatorial district unrepresented, who shall then be awarded the scholorship for the balance of the time for which said district would originally have been entitled to its benefit. In case a vacancy occurs in any senatorial district after an appointment has been made, then a candidate from the same district shall be selected for the balance of the time for which said district is entitled to its benefit, or in the event of no such candidate appearing, from the State at large, upon the conditions previously set forth: *provided*, that said corporation shall secure, prior to the first payment above authorized, a further sum of one hundred thousand dollars in addition to the funds now held by it and to be applied to the purposes of the said Institute, and shall present satisfactory evidence thereof to the Auditor of the commonwealth. [*Approved June 16, 1887.*

REMARKS OF THE PRESIDENT OF THE INSTITUTE,

Addressed to the Graduating Class of 1887, May 31.

It is now my pleasant duty, on behalf of the Corporation and Faculty of the Massachusetts Institute of Technology, to present to you the diplomas of your honorable graduation, and to greet you Bachelors of Science.

What we have said in these testimonials we truly and fully mean. All that is here written is to be taken without discount, qualification, forced construction, or academic fiction. These diplomas testify to four years of hard, patient, self-denying, and persistent study and practice, week by week, month after month, in science and in the application of scientific principles to the arts of life. All this is precisely true in the case of each and every one of you.

And on behalf of your teachers, I gladly bear witness to the cheerfulness, courage, and zeal with which you have met the exacting requirements of our curriculum; the fidelity and high sense of honor and duty with which you have borne yourselves through these trying years of laborious study. Those qualities have won the respect and affection of your instructors here; they cannot fail to secure recognition and command confidence in the new lives on which you are entering today.

Fortunate are they who, in opening a new chapter of life, are not required to do what is implied in that ominous phrase, "turning over a new leaf." You are not now called upon to close a career of dissipation, or idleness, or frivolity, or triviality, with good resolutions of amendment and

reformation for the future. Your friends and teachers are not counting the chances that the closer contemplation of life's responsibilities, or perhaps the actual pressure of its burdens, will sober your minds, give you a serious sense of duty, and inspire you for the first time with a strong and controlling purpose. All this has already been done in your case: else you would not now be here.

I would not speak to you as if your characters were altogether formed, your education completed, or the last of the perils that beset life were happily passed. Much, very much, remains; but it is not by turning around in your course, but by following on as you have so well begun, that you are to pursue your voyage and reach the haven of your hopes and rightful ambitions.

It is always a long and weary way which involves the retracing of steps that have gone in the wrong direction, or the making up of time that has been wasted; and I cannot sufficiently congratulate you that you have taken the morning of life, while the heart is buoyant within, the limbs stout and active, and the air around fresh and fragrant, and the sun is yet low in the heavens, to make so strong and stalwart a beginning of your journey. I cannot believe that, as you pause on this eminence, here on your graduation day, and look back and down upon the camps of those who have not yet girded themselves for the march, but are still resting in the comfortable belief that it will do as well to begin life in earnest at twenty-one or twenty-five, you are at all disposed to regret your own early start and the manful exertions to which you have given the dewy hours of morning.

My friends, the point toward which all your studies and exercises have been directed these long years is at length reached; the hour has come for you to say good bye to each other and to your teachers, and with brave and hopeful hearts step over the threshold of the school out into the wide world of action.

1143

Mass. Institute of Technology.

PRESIDENT'S REPORT,

DEC. 12, 1888.

BOSTON.
ALFRED MUDGE & SON, PRINTERS,
No. 24 Franklin Street.
1888.

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FRANCIS A. WALKER.

To the Corporation of the Massachusetts Institute of Technology:

It is my pleasant duty to report to you the experiences of the Institute of Technology during the year, which has been, perhaps, the most fortunate and prosperous in our history, even among the many prosperous and fortunate years which we have, of late, enjoyed. The gains realized in the number of our students, and in our material means, have not been more remarkable than the improvement that has taken place in the variety and extent of the instruction given, in the quality of the classes coming to claim the benefits of that instruction, and in the general tone and spirit of the school. Never before has the Institute been in a position of equal usefulness; never have its professors and instructors felt themselves so well repaid for all their exertions and sacrifices by the fruits of their labors, in the formation of character, in the growth of intellectual power, in the discipline of the faculties, and the acquisition of useful knowledge on the part of their students. With a full heart, I congratulate this Corporation, whose members have given to the interests of this School of Industrial Science such close attention and such generous support, together with the ripest fruits of their own large and varied experience of affairs, upon the high degree of success which has crowned their efforts.

THE GRADUATING CLASS.

The last school year closed fortunately. The class of 1888 graduated on the 29th of May. Of the 78 students of the fourth year, who were candidates for the degree of

Bachelor of Science, 77 were admitted to that grade by your authority, upon the recommendation of the Faculty. Never before has the proportion of applicants failing upon their final examinations and their thesis work been so small.

Not only was the class thus graduating the largest in our history, but in scholarship, in mental strength, and in manliness of character, it was a class which the Alumni of the Institute may be proud to add to their rolls. At the simple exercises of our graduation day, the class of 1888 were most happy in hearing words of counsel and cheer from the eloquent lips of Dr. Phillips Brooks, once a member of this Corporation.

THE NEW YEAR.

The opening of the academic year, 1888–89, witnessed an addition to the lists never but once equalled in our experience. The number of students in the School of Industrial Science, as by the Catalogue recently issued, is 827, against 720 reported last year, an increase of 107.

The following table exhibits the number of students in the School of Industrial Science each year, from the opening of the Institute to the present time:

Year.	No. of Students.	Year.	No. of Students.
1865–66	72	1877–78	194
1866–67	137	1878–79	188
1867–68	167	1879–80	203
1868–69	172	1880–81	253
1869–70	206	1881–82	302
1870–71	224	1882–83	368
1871–72	261	1883–84	443
1872–73	348	1884–85	579
1873–74	276	1885–86	609
1874–75	248	1886–87	637
1875–76	255	1887–88	720
1876–77	215	1888–89	827

I cannot forbear to repeat here the words I used in the same connection in my report of last year: —

"Had the remarkable increase in the number of students since 1878 been secured by any lowering of the standard of scholarship, any surrender of the requirements for admission, for continuance in the school, or for graduation from it, that increase of numbers would not be to me a subject of pride or pleasure; but when I consider that this increase has taken place coincidently with a steady advance in scholarship; that these great bodies of students have come to us well knowing that the Institute is a place for hard study, and cheerfully accepting the conditions which we impose: this, I confess, appears to me a proper subject for congratulation. Not only so, but this readiness and eagerness on the part of so many young men to undertake severe and protracted courses of study, regarding which there can be no pleasing illusions, and which require the entire devotion of time and thought and strength for four years, affords a most gratifying indication of the essential manliness of young men."

I do not see how the Corporation can fail to derive from this unprecedented resort of students to the halls of the Institute a strong assurance that there is something in the scheme of instruction which has been slowly built up here, during the past twenty-three years, especially in the close combination of theory with practice, so marked a characteristic of our system, which makes this school peculiarly useful to young men.

STUDENTS BY CLASSES.

The aggregate number of students for 1888–89 is divided among the several classes as follows: —

Graduate student, candidate for an advanced degree		1
Regular students,	Fourth Year	74
" "	Third Year	120
" "	Second Year	144
" "	First Year	251
Special students		237

Assigning the special students to classes according to the predominant studies pursued by them, we reach the

following statement of the division of the whole body among the several years: —

Class.	Regular.	Special.	Total.
Graduate of the M. I. T.	1	..	1
Fourth Year	74	28	102
Third Year	120	49	169
Second Year	144	81	225
First Year	251	79	330
	590	237	827

STATISTICS OF EXAMINATIONS.

The results of the applications for admission to all classes of the School of Industrial Science, thus far in the current school year, and of the examinations had thereupon, may be stated as follows: —

Eighty-seven were admitted without examination, either to the first-year class, upon presenting certificates of clear admission to some college of reputable standing, or, upon the presentation of diplomas of graduation from some degree-conferring institution, classical or scientific, to our second or third year class as regular students, or to some department as special students; 189 were admitted upon examination, free of conditions; 69 were admitted with one condition imposed, 30 with two conditions, 23 with three conditions, 16 with four conditions; 62 applicants were rejected upon examination. The proportion of applicants receiving more than one condition, at the entrance examinations, is slightly greater than it was last year. This does not, however, as might be thought, represent a lower degree of preparation, on the part of the incoming class, but is due to the further division of the examinations heretofore given in what are called "English Studies." For-

merly two marks, only, were given on account of English, history, and literature. This year the Faculty, with a view to emphasize the importance of these subjects to students entering the Institute, and thus, so far as in them lay, to promote a more careful and extended preparation, on this side, in the "fitting schools" and academies, divided this group of subjects into three heads, giving a separate examination in each, and a distinct mark on each account. It was in this way that the number of conditions given was increased. On the other hand, the proportion of students admitted free of conditions in mathematical subjects was smaller than ever before.

The total number of applicants appears, therefore, to have been 476. Of those admitted upon examination, 52 have not thus far entered the school. In some instances, in the case of applicants heavily conditioned, this has been due to the advice of the Faculty that a longer period be taken for preparation; in some, to a change of plans, to sickness, or other causes.

EXAMINATIONS AT DISTANT POINTS.

In addition to the entrance examinations held in Boston in June and September, 1888, examinations were also conducted, in June, at Chicago, Cincinnati, Kansas City, Montreal, Nashville, New York, Philadelphia, Pittsburg, San Francisco, Santa Fé, St. Louis, St. Paul, and Washington.

STATISTICS OF RESIDENCE.

Thirty States of the Union, besides the Territories of Dakota, Wyoming, and New Mexico, and the District of Columbia, are represented in our lists of students. Canada, Greece, Ireland, Scotland, Peru, Brazil, Guatemala, Turkey, the West Indies, and the Hawaiian Islands have also sent us students.

Of the total number of 827, including special students, 494 are from Massachusetts, or 59.7 per cent of the whole; 105 are from other New England States; 211 from outside New England, of whom 17 are from foreign countries.

The following table shows the number of students of each specified class, from each State or foreign country:—

State.	Candidates for Advanced Degrees.	Fourth Year.	Third Year.	Second Year.	First Year.	All Regular Students.	Special Students.	Total.
Arkansas	....	..	1	1	...	2	...	2
California	....	2	3	1	3	9	4	13
Colorado	....	..	...	1	1	2	...	2
Connecticut	....	..	3	9	11	23	5	28
Dakota	....	..	1	...	...	1	...	1
Dist. Columbia	....	..	...	2	4	6	3	9
Georgia	....	..	...	...	1	1	...	1
Illinois	....	2	7	7	12	28	9	37
Indiana	....	..	...	...	...	...	1	1
Iowa	....	2	1	...	...	3	3	6
Kentucky	....	..	1	...	1	2	1	3
Louisiana	....	..	...	...	2	2	...	2
Maine	....	2	1	7	6	16	10	26
Maryland	....	1	1	...	1	3	1	4
Massachusetts	....	53	73	85	154	365	129	494
Michigan	....	1	...	3	4	8	4	12
Minnesota	....	..	2	...	4	6	2	8
Missouri	....	..	...	1	2	3	4	7
Nebraska	....	..	1	...	...	1	1	2
N. Hampshire	....	3	3	3	8	17	7	24
New Jersey	....	1	2	...	1	4	4	8
New Mexico	....	..	...	...	2	2	...	2
New York	....	2	4	11	4	21	10	31
No. Carolina	....	..	...	...	1	1	...	1
Ohio	....	1	6	2	6	15	8	23
Oregon	....	..	...	1	...	1	...	1
Pennsylvania	1	1	2	2	4	10	8	18
Rhode Island	....	2	5	2	5	14	8	22
Tennessee	....	..	...	1	1	2	1	3
Texas	....	..	...	...	...	...	2	2
Vermont	....	..	1	...	1	2	3	5
Virginia	....	..	...	...	1	1	3	4
Wisconsin	....	..	...	2	4	6	1	7
Wyoming	....	..	1	...	...	1	...	1
Foreign Country.								
Brazil	....	..	...	...	1	1	1	2
Greece	....	..	...	...	1	1	...	1
Guatemala	....	..	...	...	1	1	...	1
Hawaiian Islds	....	..	...	...	1	1	...	1
Ireland	....	..	...	1	...	1	...	1
N. Brunswick	....	..	..	...	1	1	...	1
Peru	....	..	1	...	...	1	1	2
Porto Rico	....	..	...	1	1	2	...	2
Prv. of Ontario	....	..	1	...	...	1	1	2
" " Quebec	....	..	...	...	...	...	1	1
Scotland	....	..	...	...	1	1	...	1
Trinidad	....	..	...	...	..	...	1	1
Turkey	....	..	...	1	...	1	...	1
	1	74	120	144	251	590	237	827

RESIDENCE OF MASSACHUSETTS STUDENTS.

It has been said that 59.7 per cent of all our students are from Massachusetts. All the counties of the State, except the small counties of Dukes and Nantucket, send students to the Institute of Technology. Ninety-four cities and towns are reported on the lists. The first column of

the following table shows the number of cities and towns in each county sending pupils to the Institute; the second column gives the aggregate number from each county. It appears that Suffolk furnishes us 183 pupils; Middlesex comes next, with 143; Essex third, with 45; Norfolk fourth, with 43:—

County.	No. of Towns.	No. of Students.	County.	No. of Towns.	No. of Students.
Barnstable . .	2	4	Hampden . .	4	6
Berkshire . . .	4	4	Middlesex . .	27	143
Bristol	4	25	Norfolk . . .	14	43
Essex	14	45	Plymouth . .	12	24
Franklin . . .	1	2	Suffolk . . .	2	183
Hampshire . .	1	2	Worcester . .	9	13
	26	82	Total . . .	94	494

The following is a list of the towns, twenty-eight in number, which send four or more scholars to the Institute:—

Boston 170	Taunton 8	Canton 4
Newton 32	Winchester . . . 8	Framingham . . 4
Cambridge . . . 22	Fall River . . . 7	Gloucester . . . 4
Chelsea 13	Malden 7	Hanover 4
Brookline . . . 11	Melrose 7	Lynn 4
Lowell 11	Newburyport . . 6	Medford 4
Somerville . . . 11	Hyde Park . . . 5	Peabody 4
Salem 9	Stoughton . . . 5	Watertown . . . 4
Lawrence . . . 8	Waltham 5	Weymouth . . . 4
New Bedford . . 8		

PROPORTION OF OLD AND OF NEW STUDENTS.

The following table exhibits, for each year of the school's history, the distribution of the total number of students among two classes: first, those students whose names are

found upon the catalogue of the year preceding; and secondly, those students whose names appear as new names upon the catalogue of the year to which the statement relates: —

Year.	(1) Total No. of Students.	(2) No. of Students in the Catalogue of the previous year who remain in the Institute.	(3) No. of New Students entering before issue of Catalogue.	(4) Of those in column (3) the following number are regular first-year Students.	(5) No. of New Students not of the regular first-year class.
1866–67	137	34	103	58	45
1867–68	167	79	88	54	34
1868–69	172	82	90	50	40
1869–70	206	90	116	63	53
1870–71	224	109	115	71	44
1871–72	261	122	139	82	57
1872–73	348	173	175	112	63
1873–74	276	171	105	59	46
1874–75	248	159	89	35	54
1875–76	255	139	116	65	51
1876–77	215	130	85	31	54
1877–78	194	96	98	47	51
1878–79	188	99	89	34	55
1879–80	203	102	101	34	67
1880–81	253	121	132	62	70
1881–82	302	136	166	86	80
1882–83	368	173	195	114	81
1883–84	443	231	212	140	72
1884–85	579	311	268	186	82
1885–86	609	369	240	177	63
1886–87	637	379	258	190	68
1887–88	720	396	324	229	95
1888–89	827	465	362	245*	117

It appears from the foregoing that the number of students remaining over has been increased by 69, while the number registered for the first time is larger by 38, making the net gain, as previously stated, 107.

The increase since 1886–87 of students not of the first-year class represents, in the main, students coming to us from other institutions, from which they have graduated,

* In addition, 6 students are repeating the first year.

or in which they have pursued their studies for one, two, or three years.

AGES OF STUDENTS ON ENTRANCE.

The next table exhibits the ages of our students upon entrance. The regular students of the first-year class number 251. From these we should except five cases of students of unusual ages: viz., three of 22, one of 25, and one of 26 years. These deductions leave 246 as the number of students whose ages have been made the subject of computation.

The results appear in the following table, in comparison with the corresponding results for 1887–88: —

Period of Life.	1887–88.		1888–89.	
	Half-Year Groups.	Yearly Groups.	Half-Year Groups.	Yearly Groups.
16 to 16½ years	3	..	3	..
16½ to 17 years	13	16	10	13
17 to 17½ years	34	..	23	..
17½ to 18 years	41	75	43	66
18 to 18½ years	42	..	53	..
18½ to 19 years	28	70	39	92
19 to 19½ years	30	..	25	..
19½ to 20 years	16	46	19	44
20 to 20½ years	12	..	16	..
20½ to 21 years	4	16	6	22
21 to 22 years	5	5	9	9
	228	228	246	246

From the foregoing tables it appears that the average age of the 246 students taken for this comparison, the present year, is 223.50 months, or 18 years, 7 months, and 15 days. This compares with the corresponding figures relating to the two previous entering classes as follows: —

	Av. Age in Months.
Class of 1889	218.53
Class of 1890	219.91
Class of 1891	221.55
Class of 1892	223.50

The progressive enhancement of the age of students, upon entrance, is partly due to general causes operating to bring students to colleges or to scientific schools at a later age; partly to the effect of a rule adopted by the Faculty of the Institute of Technology, three years ago, fixing the minimum for admission, except in extreme cases, at 17 years. To this rule, as stated, exceptions are allowed, especially between the age of 16½ and 17, in regard to students more than usually well prepared, or where good reasons exist for deeming it unwise to hold the applicant back for another year. But, in general, the rule is enforced with excellent effect. Even if the time of entrance should be still further protracted, our students would, nevertheless, graduate at an age youthful enough for the beginning of professional life and practice.

In this connection it may be interesting to note the ages at graduation of the class leaving us in May. The 77 members of the class were distributed among the several periods of life, as follows: —

Under 20	4	Between 22 and 23	23
Between 20 and 20½	6	" 23 and 24	5
" 20½ and 21	6	" 24 and over	12
" 21 and 21½	8		
" 21½ and 22	13		77

PROPORTION OF REGULAR AND OF SPECIAL STUDENTS.

The following table exhibits both the absolute number of regular and of special students, as by the catalogue of each successive year, and the proportion existing between these two classes: —

Year.	No. of Regular Students.	No. of Special Students.	Total No. of Students.	Percentage.	
				Regular.	Special.
				Per cent.	Per cent.
1865–66	64	8	72	89	11
1866–67	110	27	137	80	20
1867–68	124	43	167	74	26
1868–69	105	67	172	61	39
1869–70	125	81	206	71	29
1870–71	143	81	224	64	36
1871–72	180	81	261	69	31
1872–73	235	113	348	68	32
1873–74	182	94	276	66	34
1874–75	170	78	248	69	31
1875–76	182	73	255	71	29
1876–77	134	81	215	62	38
1877–78	117	77	194	60	40
1878–79	103	85	188	55	45
1879–80	110	93	203	54	46
1880–81	140	113	253	55	45
1881–82	164	138	302	54	46
1882–83	219	149	368	60	40
1883–84	272	171	443	61	39
1884–85	368	211	579	64	36
1885–86	415	194	609	68	32
1886–87	442	195	637	69	31
1887–88	520	200	720	72	28
1888–89	590	237	827	71	29

It will be noted that there has been a slight increase in the proportion of special students since my last report, the per cent having risen from 28 to 29. That is, six more students appear this year as "specials" than would have maintained the proportion existing in 1887. It is likely that the entire effect in this direction may have been caused by the earlier date of sending the list of students for the annual Catalogue to the printer this year, some students not having, at that date, arranged their courses in such a way as to become "regulars." But of far greater influence in increasing the list of special students, this year, has been the remarkable addition made to the department of Architecture, the number of students in this course hav-

ing increased fifty per cent. But for this, the proportion of special to regular students in the school, as a whole, would have fallen to 25 per cent, or lower.

WOMEN AS STUDENTS IN THE INSTITUTE.

The number of women pursuing courses with us last year was 25; this year it is 33, of whom 5 are graduates of colleges. Of the total number, 2 are regular students of the third year; 2 of the second year; 3 of the first year; 26 are special students. Of the 4 regular students of the upper classes, 1 takes Course IV., architecture; 1 Course V., chemistry; 1 Course VII., natural history; 1 Course IX., the general course. Of the special students, 15 devote themselves chiefly to chemistry and physics; 9 chiefly to biology and allied subjects; 1 to mathematics; and 1 to architecture.

GRADUATES OF OTHER COLLEGES.

Thirty-four graduates of institutions conferring degrees are included in our list of students for the present year. Of these, 1 is our own graduate, pursuing advanced studies as a candidate for the degree of Doctor of Philosophy. Thirty-three are graduates of other institutions, either scientific or classical, pursuing courses of study with us, either as regular students, candidates for our Bachelor's degree, or as special students. Of these, 9 are graduates of Harvard University, 4 of Brown University, 3 of Yale University, 2 each of Vassar College and Georgetown College, while 1 comes from each of the following institutions: Oxford University, University of Minnesota, University of the Pacific, Iowa State University, Oregon State University, Union College, Oberlin College, Wellesley College, Smith College, Hobart College, Haverford College, St. John's College, and St. Mary's College.

Of the 33, 1 is a regular student of the fourth year in civil engineering; 9 are regular students in the third year, — 3 in mechanical engineering, and 2 each in civil engineering, architecture, and electrical engineering; 2 are regular students in civil engineering, and 2 in electrical engineering, in the second year; 1 is a regular student in the first year. The remaining 18 are special students.

THE COURSES OF INSTRUCTION.

The following table presents the number of students in each of the regular courses. It will be seen that this statement relates to the second, third, and fourth years, choice of courses being made only at the end of the first year: —

Year.	Civil Engineering.	Mechanical Engineering	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Electrical Engineering.	Natural History.	Physics.	General Course.	Chemical Engineering.	Total.
4th Year Class . . .	17	22	3	3	7	18	..	2	2	..	74
3d " " . . .	28	36	5	8	9	22	2	2	8	..	120
2d " " . . .	26	42	4	10	12	34	2	1	2	11	144
Total	71	100	12	21	28	74	4	5	12	11	338

The distribution of the students of the fourth year among the different branches of those courses in which there are distinct lines of choice, is as follows: —

Of the 17 students in Course I., 14 follow the traditional line of civil engineering, while 2 have taken railroad engineering and 1 the option in geodesy and geology.

Of the 22 students in mechanical engineering, 4 are taking the marine engineering option, 5 the locomotive engineering option, and 13 the mill engineering option.

The Catalogue for 1888–89 shows the number of instructors of all grades, excluding those persons who are announced as lecturers for the year only, to be 79, against 75 last year.

The following table shows the number of teachers of each recognized grade, exclusive of the department of Mechanic Arts, in each year since the foundation of the school: —

Year.	Professors.	Associate Professors.	Assistant Professors.	Instructors.	Assistants.	Total.
1865–66	10	..	..	..	..	10
1866–67	12	..	..	2	..	14
1867–68	12	..	1	2	2	17
1868–69	13	..	..	6	1	20
1869–70	16	..	1	6	2	25
1870–71	18	..	2	7	5	32
1871–72	21	..	2	11	1	35
1872–73	23	..	2	9	1	35
1873–74	20	..	3	10	4	37
1874–75	20	..	3	7	3	33
1875–76	23	..	..	6	8	37
1876–77	21	..	..	4	10	35
1877–78	20	..	..	3	14	37
1878–79	18	..	..	7	12	37
1879–80	16	..	..	7	8	31
1880–81	15	..	2	6	7	30
1881–82	17	..	3	6	11	37
1882–83	16	..	3	10	11	40
1883–84	15	..	8	15	10	48
1884–85	14	3	11	15	14	57
1885–86	14	6	7	17	18	62
1886–87	12	7	6	27	17	69
1887–88	13	6	9	30	17	75
1888–89	12*	7	10	32	18	79

CHANGES IN THE FACULTY AND THE CORPS OF INSTRUCTORS.

The Faculty and the school have suffered a great and painful loss, since the present academic year began, by the

* Since the Catalogue was sent to press has occurred the death of Prof. Otis, which will be referred to in a later part of this report. The tables relating to instructors are made up from the facts of the Catalogue.

death of Prof. Charles P. Otis, who has, for sixteen years, been at the head of the department of Modern Languages in this institution. Prof. Otis's health gave way, in a most critical manner, toward the close of the last school year; and his place in the work of instruction was immediately supplied, in order that he might have the fullest opportunity for rest and recovery. During the summer, hope was entertained by himself and his friends that he would be able to resume his duties the present year; but, as the season approached, it became painfully evident that his restoration to full working strength was not to take place so soon, if ever. The Executive Committee of the Corporation promptly granted him a leave of absence for the year, which he accepted with the purpose of seeking health in Germany. Early in November, however, a critical change for the worse appeared, and he rapidly declined until his death, on the 17th of that month. The cause of his untimely decease was an obscure cerebral affection, which, though unsuspected, had probably been long coming on.

Prof. Otis was born in Lebanon, Conn., in 1840; prepared for college at Phillips Academy, Exeter, N. H.; and, entering Yale College in 1857, graduated with high rank in 1861. For four years after his graduation, he taught school in Fairfield and in New Haven, Conn., and was then, for an equal period, a tutor in Yale College. He went abroad in 1869, for three years of study in Paris and Berlin. On his return he became a pupil of Whitney, in New Haven, receiving the degree of Ph. D. from Yale College in 1873. In the same year he became Professor of Modern Languages in the Institute of Technology.

Prof. Otis was a ripe scholar, a laborious student, a painstaking teacher, a scrupulously faithful and diligent member of the Faculty of the Institute. His sterling sense of justice, his quiet enthusiasm, and uniform kindness attached his students strongly to him; and of the many classes which have graduated from the Institute

since he took the chair of Modern Languages there are few members who do not owe to him much of their preparation, in mind and character, for the duties of life. Prof. Otis had published a text-book of "Elementary German," widely used among the colleges of the country, and had edited, to the great satisfaction of the scholarly world, several important German texts. He had also printed, but not published, an outline of Middle High German Grammar and selections from the *Nibelungen Lied.*

During the past year, the Executive Committee reached the conclusion, to which various considerations had seemed for some time to point, that, in the growth of the Institute and the increase of the instructing staff, it had become desirable that the classes in Zoölogy and Palæontology should be taught within the lecture-rooms and laboratories of the Institute itself. In accordance with this view, so much of the arrangement between the Institute of Technology and the Boston Society of Natural History as provided for the instruction of our classes by the Custodian of the latter society, was, after due notice, terminated; and the instruction in those subjects was charged upon Prof. Sedgwick and Dr. Gardiner.

In thus terminating an arrangement which had existed, with mutual advantage to both institutions, through a long term of years, the Faculty and the Corporation were not insensible of the extraordinary merits of Prof. Hyatt, Custodian of the Boston Society of Natural History, whether in scientific discovery or in the popular exposition of natural laws. The action recited was taken under the conviction that the time had come, in the development of the Institute, when the instruction given in the several departments of natural history should be more closely coordinated than had previously been possible, and that the students of these departments should receive all their regular or ordinary instruction within the walls of the Institute.

Another important change within the Faculty during the past year has resulted from a somewhat similar cause. It has for some time seemed desirable that the large and growing department of Architecture should have for its head a gentleman not engaged in professional practice, whose time and thought would, therefore, be given wholly and without interruption to the building up of the department, and who would be able to closely follow the course of his pupils and study their individual needs. However desirable this has seemed in the past, it has not been deemed practicable. In the provision for the present year, however, it was found possible to secure the advantages anticipated from such a course; and, in a very cordial appreciation of the best interests of the school, Prof. Theodore M. Clark, who has for seven years occupied the chair of Architecture, vacated his office to allow such an arrangement to be effected. Mr. Clark carries with him the thorough respect and warm regard of all his late associates.

The chair of Architecture has been filled by the appointment of Mr. Francis W. Chandler of this city. Mr. Chandler entered the office of Messrs. Ware & Van Brunt, as a student, in 1864. After remaining there three years he entered the *Atelier Daumet*, in Paris.

In 1869–70, Mr. Chandler was connected with the Institute of Technology as Prof. Ware's assistant in the department of Architecture. In 1871, he became assistant supervising architect of the Treasury Department, at Washington, and in that capacity took part in framing the plans of many important Government buildings. In 1874, he became associated with Mr. Edward C. Cabot, in the architectual firm of Cabot & Chandler. On accepting his appointment as Professor of Architecture, Mr. Chandler retired from practice, in order to devote his entire time and thought to the needs of the department.

Asst. Prof. Schwamb has, in recognition at once of his high professional acquirements and of his arduous labors

in the department of Mechanical Engineering and as director of the workshops, been appointed Associate Professor of Mechanism.

Dr. Davis R. Dewey, whose appointment as Instructor in History and Political Science was noted in my report of 1886, has, during the year, been promoted to be Assistant Professor of Economics and Statistics, the work in history which formerly devolved upon Dr. Dewey, together with additional duties arising from our growth in numbers, and from the increased attention given to this class of studies, having been assigned to a new member of the Faculty, Dr. Charles H. Levermore.

Dr. Levermore entered Yale College in 1875, graduating with honors in 1879. For the four years next succeeding, he was principal of the Academy at Guilford, Conn. In 1883, he entered upon a course of graduate study, in the department of history and political science, in the Johns Hopkins University, devoting a portion of his time to pedagogics and philosophy. In 1884–85, he held a fellowship in that university. In 1885–86, Mr. Levermore held the position of instructor in the Hopkins Grammar School, in New Haven, Conn. In 1886, he received the degree of Doctor of Philosophy from the Johns Hopkins University, and soon after accepted an appointment as instructor of history in the University of California. This position he resigned, on the 1st of February, 1888, to accept an appointment as Assistant Professor of History in this institution.

In addition to minor contributions to the press, Dr. Levermore has published the following results of his studies: —

First. A History of Witchcraft in Connecticut, published in the *New Englander*, in November, 1885.

Second. An Account of the Town and City Government of New Haven, a portion of his thesis for the Doctor's degree, published in the Fourth Series of J. H. U. Studies in History and Political Science.

Third. The Republic of New Haven : A History of Municipal Evolution, constituting Vol. I. of the Special Series of J. H. U. Studies in History and Political Science, 1886.

Fourth. Two chapters, on Municipal Government, in Atwater's History of New Haven, 1887.

At the middle of the last school year Mr. Arthur N. Wheelock, who had served with acceptance for two years as Instructor in English, was obliged, on account of impaired health, to relinquish his charge. Mr. Wheelock's work thus suddenly devolved upon Mr. F. B. Emery, his assistant. These onerous and responsible duties were taken up and carried on by Mr. Emery, in addition to his own proper work, with so much intelligence, spirit, and ambition as to cause his appointment, the present year, as Instructor.

On the failure of Prof. Otis's health, in March last, the Executive Committee requested Mr. W. C. Dreher to assume temporary charge of his classes in German. This was done to the entire satisfaction of the Faculty, and Mr. Dreher was appointed an Instructor for the present school year.

Mr. Dreher graduated from Roanoke College in 1878. After graduating, he taught for four years, and pursued a two years' course in theology at Yale College. He then became the Principal of the Preparatory Department of Roanoke College, occupying this position for a year, at the conclusion of which he went abroad for two years' study in France and Germany.

Mr. Eugene H. Babbitt, who was, during the last school year, an Instructor in Modern Languages at the Institute, and who had proved himself an exceedingly capable and accomplished teacher, resigned the position at the close of the last year, much to our regret, to accept a position in Harvard University. Mr. Frank Vogel, a graduate of Harvard University in the class of '87, was appointed to fill the vacancy thus occasioned.

Dr. Howard V. Frost, after two years' absence, returned to the Institute, at the opening of the school year, from Germany, where he had taken his Doctor's degree; and resumed the charge of the laboratory of General Chemistry. Mr. Frederic L. Bardwell, who, during Mr. Frost's absence, conducted the work of this laboratory to the entire satisfaction of the Faculty, remains as Dr. Frost's assistant.

Mr. Harry W. Tyler, Instructor in Mathematics, who was last year absent on leave, further pursuing his mathematical studies in Germany, still remains away. He is expected to resume his duties at the Institute at the beginning of the next school year.

Three others of the Instructors or Assistants of last year, namely, Mr. Henry P. Talbot, Instructor in Chemical Analysis, Mr. Arthur A. Noyes, Assistant in General Chemistry, and Mr. Frederick Fox, Jr., Assistant in Sanitary Chemistry, left the Institute at the close of the school year 1887–88, in order further to pursue their studies abroad.

After four years' valued service, first as Assistant and then as Instructor, in the Laboratory of Industrial Chemistry, Mr. George R. Underwood resigned, at the close of the last year, to enter into professional practice.

The following named gentlemen, graduates of the class of '86, and Assistants in their respective departments during the previous two years, have this year been appointed to the grade of Instructor: —

Mr. Dana P. Bartlett, in Mathematics; Mr. Harry E. H. Clifford, in Physics; Mr. Edward F. Miller, in Mechanical Engineering; Mr. Arthur G. Robbins, in Civil Engineering.

Mr. Dwight H. Perkins having declined reappointment as Junior Instructor in Architecture, Mr. Frank A. Moore, of the class of '88, has been appointed to that position.

The Assistants for the school year 1888–89 are as fol-

lows: Edward S. Foss, Louis E. Levi, and Edward C. Holton, in General Chemistry; Alfred J. Wakeman, Jas. W. Loveland, and Chas. Ferry, in Chemical Analysis; Arthur J. Conner, in Industrial Chemistry; Geo. L. Heath, in Sanitary Chemistry; Ralph E. Curtis, Wm. O. Hildreth, B. R. T. Collins, and Geo. W. Hamblet, in Mechanical Engineering; Jas. H. Stanwood, in Civil Engineering; Chas. F. Hastings, in Mining and Metallurgy; Fred. B. Cole, in Drawing; Edward Collins, Jr., in Physics; Amos E. Woodward, in Geology; and Arthur B. Frizell, in Mathematics.

In addition to the regular staff of instruction, the following gentlemen have been appointed lecturers for the current year: George W. Blodgett, S. B., on Applications of Electricity to Railway Working; Henry M. Howe, A. M., S. B., on Metallurgy; C. Howard Walker, on History of Ornament; Ross Turner, on Water Color and Sketching; Charles W. Hinman, S. B., on the Manufacture of Illuminating Gas; Walter S. Allen, S. B., on the Manufacture of Fertilizers; Eliot Holbrook, S. B., on Railroad Maintenance; David A. Gregg, on Pen and Ink Sketching; Anthony C. White, S. B., on the Distribution of Electricity for Commercial Purposes; Edward Blake, Ph. B., on the Construction and Applications of Electro-Motors

The following table exhibits the number of Instructors of all classes, including the lecturers appointed for the current year, assistants performing the duties of instructors, assistants in drawing rooms and laboratories, and also instructors and assistants in the mechanic arts: —

	Civil Engineering.	Mechanical Eng. and App. Mechanics.	Mining Engineering, and Metallurgy.	Architecture.	Chemistry.	Physics and Elect. Engineering.	Biology, Zoölogy, etc.	Mineralogy, Geology, and Geography.	English and Political Science.	Language.	Mathematics.	Drawing and Descrip. Geometry.	Mechanic Arts.	Military Tactics.
Professors.....(12)	1	1	1	1	1	1	....	1	2	1	2	....	....	....
Associate Professors,(7)	....	1	....	1	1	1	1	....	....	1	1	....	....	....
Assistant Professors,(10)	3	1	1	....	1	....	....	1	2	....	....	1	....	....
Instructors .....(36)	1	5	....	2	6	4	1	1	1	3	4	3	4	1
Assistants..... .(21)	1	4	1	....	8	1	....	1	....	....	1	1	3	....
Total.....(86)	6	12	3	4	17	7	2	4	5	5	8	5	7	1
Lecturers.....(10)	1	....	1	3	2	3	....	....	....	....	....	....	....	....
Total.....(96)	7	12	4	7	19	10	2	4	5	5	8	5	7	1

On account of the increase in the number of students in the laboratory of industrial chemistry, and, also, with a view to carrying further than had been possible before the instruction given in bleaching, dyeing, and coloring, Mr. John W. Smith, for several years superintendent of the Walpole Dye Works, was appointed, at the close of the last year, Instructor in Textile Coloring.

THE LOWELL SCHOOL OF INDUSTRIAL DESIGN.

No change of importance has occurred in the Lowell School of Industrial Design since my last report. The school continues its most useful work in fitting young men and young women for positions as designers, especially in connection with the textile industries, but also in many other branches of manufacture in which taste in form and color is an essential element of success. The number of students, heretofore fixed at sixty-two, has this year been, in conference between Mr. Augustus Lowell, trustee of

the Lowell Institute, and the president of the Institute of Technology, reduced to fifty-three, in order to give ampler accommodations to the students, and to allow to each a larger share of the personal attention of the instructors concerned. The exhibition of the work of the students made in May last, in connection with the graduating exercises of the Institute, I think surprised even those who had most carefully followed the development of the school, by the beauty, variety, and originality of the designs shown.

THE SCHOOL OF MECHANIC ARTS.

Very important action has been taken by the Faculty and the Corporation, during the past year, regarding the School of Mechanic Arts, which was first established in the Institute of Technology in the year 1876, under the presidency of Dr. Runkle. The object in view, in the original establishment of this school, was twofold: —

First. It was considered a means of providing for the mechanical engineering students of the School of Industrial Science workshops, machinery, and tools, which the means of the Institute did not, at that time, allow the Corporation otherwise to provide.

Secondly. To set an example of scientific instruction in the mechanic arts, in connection with ordinary high-school instruction in letters, language, and mathematics, which might be of service to the community and to the country, by promoting the general introduction of schools of this class, maintained either by private benevolence or by public grants.

The first object of the Corporation in establishing the School of Mechanic Arts was fully attained. The school, from the beginning, paid its expenses, and, moreover, furnished workshops and tools in which the then limited number of students of mechanical engineering could ob-

tain this much-needed instruction without cost to the general funds of the Institute.

Regarded as a public-spirited effort to promote a new and much-needed kind of education, the School of Mechanic Arts has justified its existence. All the schools, in this region and at the West, in which ordinary high-school instruction in letters, language, and mathematics is combined with instruction and practice in the mechanic arts, may fairly be said to be offshoots of the school established here in 1876. Some of these schools are already doing a great public service for their respective communities; and I entertain the confident expectation that the number and influence of such schools will be rapidly multiplied.

But while, thus, our School of Mechanic Arts had fully justified its establishment, from every point of view, it has for several years been evident, either that much should be done and large expenditures made, by the Corporation, for the purpose of building up this subsidiary school, or else that it should be abandoned. It is always a matter of serious question whether a preparatory school can be advantageously connected with an institution of higher learning. Experience shows that there is great danger that the preparatory school will draw away much of the vitality of the higher institution without itself being adequately benefited. In our own case, the reasons which ordinarily exist for the separation of the preparatory school, were made doubly strong by the rapid growth of the School of Industrial Science, which called for all the time and means which the Faculty and Corporation had to bestow. For two or three years, efforts have been made to secure an independent equipment and endowment for the School of Mechanic Arts; but, as these efforts proved fruitless, there seemed to be no resource but to discontinue the school. This was accordingly done by the Corporation at its May meeting, as recited; and at the same time the subject of the establishment of a high school of the mechanic arts,

for the youth of Boston was commended to the favorable consideration of the school committee of the city.

The instruction given in the mechanic arts to the students of the School of Industrial Science will in no way be affected by this action. On the contrary, the discontinuance of the subsidiary school will afford ampler accommodations and allow a freer use of the machinery and tools on the part of the engineering students.

CHANGES IN COURSES OF STUDY AND IN LABORATORY ACCOMMODATIONS.

The changes which have taken place in the established courses of study in the Institute of Technology during the past year have, in the main, been in the way of small progressive improvements or enlargements, shown by experience to be both practicable and desirable, and taking place almost insensibly.

Summer Schools. — In my last report, I stated that the Faculty, with a view to supplying a long-felt want, had made provision for a summer course in topography, geodesy, and geology, extending through the early part of the vacation following the close of the third year, in Course I. The plan thus announced was successfully carried out during the summer of 1887, at South Deerfield, Mass. The school covered a period of four weeks, of which three were devoted to topographical work, with the stadia and plane-table, base-line measurement, triangulation, hypsometric work, and a study of the geology of the region; while the remaining week was occupied in gauging the flow of the Connecticut River by various methods. The instructors in attendance were Profs. Swain and Niles, and Asst. Profs. Burton and Porter, all of whom gave their services gratuitously. Prof. Burton had immediate charge of the school during the first three weeks, while the hydraulic

work was carried out by Prof. Swain. Eight students were in attendance, all of them members of the present graduating class. They manifested, throughout, the greatest interest in the work; the health of all the members of the party was exceptionally good; and a great deal was accomplished. The object of the school, as stated in the last report, was not to complete any given piece of work, but to instruct the students in directions which cannot be sufficiently followed out in the course of the regular school year; and in doing this it was in every sense successful.

The school will be again carried on during the coming summer, at some locality not yet decided upon. The work will not be essentially different from that of last summer, except that more of purely geodetic and astronomical work will be introduced.

In addition to the summer school of topography, geodesy, and geology, for the benefit of the civil engineering department, there was instituted a corresponding course, which had been for several years in contemplation, for the students of the mining and metallurgical department. In eleven out of sixteen years, beginning with 1872, the students of this course have devoted a portion of the long vacation to excursions, sometimes extensive in their range, in the course of which important mining districts were visited, and mines and their works were inspected by the students, and made the subject of informal lectures by the instructors in charge. In one year or another, during this period, excursions of such a character have been made to Colorado, to the Lake Superior district, to Virginia, Vermont, Pennsylvania, the Lake Champlain district, New Brunswick, and Nova Scotia

In anticipation of the summer of 1888, however, it was deemed desirable to make a departure from the method heretofore pursued; and it was determined that the summer school of mines should be held in some appropriate locality for a term of six weeks; and that the students

should be given an opportunity not only to witness mining work in progress, but themselves to take part in the various operations. The locality chosen was the Eustis mine, at Capelton, Canada; and the time taken, the month of June and the first half of July. The number of students in attendance was fifteen, who were divided into squads, which worked, alternately, one week in the mine and one week above ground. The work in the mine consisted in making a survey, as complete as possible, of the whole mine, and in determining the location of several vertical shafts, at the surface, which should strike the vein from 600 to 1,500 feet lower down upon the slope than the present workings. Profiles of the several shafts were run to show their irregularities, and to indicate the amount of work which would be required to straighten them. The students all took a four days' turn at drilling and blasting; and in this, as in many other ways, they quite won the hearts of the miners by the readiness with which they acquired both the skill and the judgment required for economical mining. They also took a turn at setting timbers and laying track.

The work on the surface consisted in examining and reporting upon the methods of sorting and shipping the ore, and in making assays of some of the products; also, in carrying on a geological survey of the locality, which brought out some new features of the structure of the mountain that had not before come to light, and that proved of considerable interest, in connection with the deposit of valuable mineral.

As there were no boarding-houses in the vicinity, the students camped out in tents brought with them from Boston. The camp proved a very comfortable one; and uniform good health was maintained. The cost of subsistence was $1.00 per day per scholar, not including fares to and from Boston. Both Prof. Richards and Asst. Prof. Clark were in attendance upon this school throughout its entire course.

The instructors who had charge of the summer school of mines are enthusiastic as to the practical results immediately attained, and still more so as to the influence of such a term of experimental work upon the subsequent career of the students engaged. They have already found, during the course of the present school year, that the students who have had this experience occupy a different mental attitude, when in attendance on the mining lectures, from those who did not share that experience. So clear are they in this judgment that it is probable the Faculty will soon seriously consider the expediency of making attendance on a summer school of mines, at the end of the second year, and a summer school of metallurgy, at the end of the third year, a positive requirement, in the first case for those who purpose to graduate in mining, and in the second case for those who purpose to graduate in metallurgy.

It is due to the Eustis Copper Mining Company, to Mr. W. E. C. Eustis, president, and to Mr. John Blue, superintendent, that acknowledgment should be publicly made for the valuable opportunities enjoyed by our students, and for the practical assistance freely rendered them.

Course I. — The most notable change in the course in Civil Engineering, in preparation for the present year, has been the introduction of a brief course in mechanism, to be followed by a course in motors. This change is in the same direction with several which have taken place during the past few years, and with others which are now in contemplation, all tending to make instruction in mechanism common to several departments of the school, and to introduce the students of these courses, to a greater or less extent, into the laboratory of mechanical engineering. The students of electrical engineering have, from the first, had the free use of the mechanical engineering laboratory, equally with the students of that department. The students in the new course in chemical engineering (hereafter to be spoken of) are, also, to be introduced largely

into the same laboratory. The students of civil engineering, as just now recited, are to take a briefer course in mechanism and in motors, while the Faculty are considering the expediency of so modifying the mining course as to present two broad lines of study in that department, the one predominantly chemical, the other predominantly mechanical, the latter containing no inconsiderable amount of instruction in mechanism and mechanical engineering.

It is thus coming about that, instead of being used by the students of one course only, the mechanical engineering laboratories are of almost as general use in the school as the laboratory of physics. This wide extension of the service of the mechanical engineering laboratories, which has been suggested, not so much from within as from without, by the course of practice in the several engineering professions, has caused a great pressure upon the accommodations of that department; and it appears to be imperative, in the immediate future, to largely increase the space devoted to this service.

In my last report, I mentioned the appointment, by the Railroad Commissioners, of Prof. Swain, of the Institute, as the bridge expert of the Board, under the statute of 1887. Prof. Swain has been since that time engaged on careful and critical studies of the railroad bridges of the Commonwealth, both in the office and in the field. The work has lasted until the present time, and is not yet completed, since every railroad bridge in the State has to be carefully scrutinized. The accident, which occurred in July last, at the Fitchburg Railroad station in this city, by which a train fell through the piled bridge, led to an investigation by Prof. Swain, under the direction of the Railroad Commissioners, regarding the causes of the accident, together with a full discussion of piled structures in general, and of their liability to decay, and to the hostile action of marine animals.

Course II. — The Mechanical Engineering department has received the following gifts during the year: an Ashworth carding engine from the Messrs. Ashworth Bros., and a complete set of Westinghouse air-brake apparatus, from the Westinghouse Air Brake Co.

The mill engineering option has been transferred to Associate Prof. Schwamb; Asst. Prof. Peabody assuming charge of the marine engineering option, and Prof. Lanza the instruction in locomotive engineering.

Among the publications issuing from the department during the year may be mentioned: —

(*a.*) A book of Steam Tables, calculated and published by Asst. Prof. Peabody.

(*b.*) Notes on Dynamometers, Planimeters, Governors, and Fly-Wheels, printed for the use of our students, but not published, by Prof. Lanza.

(*c.*) A Paper on the Transverse Strength of Cast Iron, presented to the Society of Mechanical Engineers, by Prof. Lanza, embodying the theses of Messrs. Cochran of the class of '85, Burgess and Vielé of '86, and Eastman and Gerrish of '88.

(*d.*) A Paper on Balancing the Throw of the Reciprocating parts of a Locomotive, presented to the same society by Prof. Lanza, embodying the theses of Messrs. Dewson of '85, Reynolds of '86, and Smith of '88.

(*e.*) A Paper on the Flow of Steam in a Tube, presented by Asst. Prof. Peabody, embodying the thesis of Mr. B. G. Buttolph, of the class of '88.

In anticipation of the thesis work of the present year, several students of the now fourth-year class did an unusual amount of investigation and experiment during the last summer, some of it consisting of tests of rather large plants.

The drawing-rooms, lecture-rooms and laboratories occupied by this department are now crowded to their utmost capacity. To get through the present year it has been

necessary to assign room 44 in the Rogers Building to this department, in addition to those already occupied by it.

In consequence of the general interest awakened in the subject of heating passenger cars by steam from the locomotive, by recent railroad accidents, the Railroad Commissioners of Massachusetts employed Prof. Lanza to examine into the systems at work in this State, and also to make an investigation of the system on trial on the Atchison, Topeka and Santa Fé Railroad, in order to ascertain what could and what could not be expected of these methods of heating cars, and thus to aid the Commissioners in deciding what legislation it was desirable to recommend in the matter. Prof. Lanza undertook his investigation in December, 1887, and completed it March 30, 1888, when he presented his report to the Commissioners. He was assisted in the experimental part of the work by Mr. A. H. Twombly, of the class of '87.

Course III. — I have already mentioned that the course of studies in the department of Mining and Metallurgy is now undergoing an extensive revision. It is probable that the next report of the President of the Institute will have much to say regarding this important department of the school ; but at the present time nothing requires to be added under this head.

Course IV. — In the architectural department of the Institute no important change has occurred so far as the regular course is concerned ; but much has been done to strengthen and enrich the two years' partial course, by the introduction of mathematics and French, as required subjects in the first year, and by general rearrangement of studies. The number of students in this department has increased by one half since last year, and the spirit pervading the body of students exhibits the most marked and gratifying improvement.

Course V. — In Chemistry, the most important change in the course of instruction during the year has been

through the considerable extension of the work in Industrial Chemistry. Students in this branch have been allowed one additional half-year in the industrial laboratory ; and a new course of lectures in Textile Coloring has been introduced. The increased number of students in the first year has rendered it necessary to add thirty-two new desks to the laboratory of general chemistry, which now has accommodations for three hundred and twenty students.

The examination of the waters of Massachusetts, on behalf of the State Board of Health, begun in 1887, by Prof. Drown and Mrs. Richards, with a corps of assistants, in room 36 of the new building, as mentioned in my report of last year, has been continued actively down to the present time. On the 1st of December, 1888, there had been analyzed nearly 3,700 samples of water. There has recently been undertaken an examination of the ice supplies of the State, also on behalf of the Board of Health, which will be continued through the winter. This great work of the Commonwealth, for the protection of its water supplies, offers to the department of Sanitary Chemistry an exceptional opportunity for the scientific study of the subject of drinking water, concerning which there has been heretofore but imperfect knowledge.

Courses VI. and VIII. — In the various courses in Physics and Electrical Engineering, the year has not been marked by changes of magnitude, but these courses have been strengthened and modified in various ways so as to obtain greater efficiency in teaching, or a better economy of time on the part of the student, thus securing a gradual advance in the standard of the instruction given. During the school year, 1887–88, six papers from the Rogers Laboratory of Physics were published in the " Proceedings of the American Academy of Arts and Sciences," the "Technology Quarterly," or elsewhere. Three other papers are now prepared for publication, and several more will shortly be ready. These papers all contain genuine, and, in some

cases, even noteworthy, additions to our knowledge of physical phenomena or laws.

The work in Electrical Engineering has reached a stage of advancement such that the department has felt ready to assume the responsibility of laying out a course of advanced instruction, embracing electricity, analytical and applied mechanics and mathematics, which can be pursued by graduate students, and which may lead to the degree of Master of Science or Doctor of Philosophy. It is not expected, or indeed desired, for the present, that the number of such students shall be large, but the presence of a few more advanced workers could not fail to exert an excellent influence over the undergraduate students.

In the matter of apparatus, the newly acquired facilities for instruction in the theory and use of dynamo-electric machinery should be noticed. The Edison dynamo and electric lighting plant, the gift of Mr. Edison, alluded to in the report of last year, and at that date in process of installation, have been of the greatest value in this respect. To these has just been added, through the generosity of the Thomson-Houston Electric Company, a large constant-potential dynamo, a type of machine the need of which has been strongly felt both by teachers and students. The laboratory now possesses the dynamo-machines of Gramme, Brush, Weston, Edison, and the constant-potential dynamo of the Thomson-Houston Company, together with a large dynamo, devised especially for experimental purposes, and constructed by Messrs. Crane and Merriam, students of the class of 1886, in connection with their graduating theses. An alternating-current dynamo will shortly be added to these, which will make the equipment of the physical laboratory, on this side, remarkably complete.

The increase in the number of machines available, and the constancy with which they had come to be employed, owing to the large body of students in this department,

rendered it absolutely necessary to the maintenance of proper instruction, that better facilities for steady driving of these machines, as well as more space in which to operate them, should be secured. There is an element of danger in crowding too many dynamos into a small space in any room frequented by students, since the amount of shafting and belting is considerable, and largely carried near the floor. Moreover, the numerous duties necessarily imposed upon the Porter-Allen engine in the Rogers Building, which has, hitherto, been the sole motive-power of the dynamos, have rendered it too unsteady to satisfy the requirements of a class of work in which lack of steadiness is a fatal defect. These difficulties have now been removed by the allotment, to the department of Physics, of a separate room, 50 x 40 feet in area, as a dynamo-room. In this room has been placed a seventy-five horse-power Westinghouse engine, mounted upon a very solid masonry pier, and assigned solely to the work of the physical department. Suitable shafting has been provided, and the dynamos are now in process of removal from their former places to the new dynamo-room. The space left in the room formerly occupied by these machines will, for the time, at least, afford a much-needed relief to the general work of the physical laboratory.

Course VII. — The number of students of the various courses and classes entering the biological laboratory, for longer or shorter courses in microscopy, in bacteriology, or in general biology, has greatly increased during the year; and, as has already been stated, to the work of this department has been added the instruction in zoölogy and palæontology, previously given by the Custodian of the Society of Natural History.

A much-needed addition to the apparatus of the biological laboratory has been supplied by the liberality of James Means, Esq., through the presentation of an expensive and very effective form of water motor, especially

adapted for aërating aquaria and for producing artificial respiration in the experiments of practical physiology.

The most marked feature in the developments of the year, in this department, has been the increase of interest within the school, and of demands made from the outside upon the school, in connection with investigations in sanitary bacteriology. The great advances recently made in this line of investigation, and the almost limitless possibilities of the future in this respect, have not only caused the minds of many of our students to turn in that direction, but have created a demand from the outside for skilled bacteriologists, which, up to this time, the Institute has not been able fully to meet. A problem of much difficulty, affecting the disposal of sewage, has lately been referred, by the State Board of Health, to Prof. Sedgwick, for investigation ; and the work thereon is now being prosecuted in the biological laboratory.

Course IX. — The body of studies in Course IX., the general course, has been still further enlarged and enriched, during the year, as a result of the appointment of Asst. Prof. Levermore, already noted.

The instruction in statistics, and in the graphic methods of representing large bodies of facts, which has been worked out by Asst. Prof. Dewey, is one of remarkable interest and usefulness. I believe that in no college of the United States is better instruction given in this important branch. Students are taught to construct diagrams and employ other modes of graphic representation, in application to a great variety of subjects, vital, industrial, commercial, and political.

Course X. — To the nine regular four-years' courses of instruction in the Institute of Technology, which have heretofore been pursued, the Faculty have this year added still another course, which is to be known as Course X., Chemical Engineering.

Eleven members of the second-year class have already

entered upon this course. A brief explanation of the general purpose for which this new department of study has been created may be of interest, not to the Corporation merely, but to the general public.

The chemical engineer has been but little known in this country or England, and perhaps not at all, under that name; although his profession is recognized in France and Germany. The chemical engineer is not primarily a chemist, but a mechanical engineer. He is, however, a mechanical engineer who has given special attention to the problems of the chemical manufacture. There are a great number of industries which require constructions, for specific chemical operations, which can best be built, or can only be built, by engineers having a knowledge of the chemical processes involved. This class of industries is constantly increasing, both in number and in importance. Heretofore, the required constructions have, generally speaking, been designed, and work upon them has been supervised and conducted, either by chemists, having an inadequate knowledge of engineering principles and unfamiliar with engineering, or even building, practice; or else by engineers whose designs were certain to be either more laborious and expensive than was necessary, or less efficient than was desirable, because they did not thoroughly understand the objects in view, having no familiarity, or little familiarity, with the chemical conditions under which the processes of manufacture concerned must be carried on. It was to meet this demand for engineers having a good knowledge of general and applied chemistry, that the course in Chemical Engineering was established.

The instruction to be given, while following mainly in the line of Mechanical Engineering, includes an extended study of Industrial Chemistry, with laboratory practice. Special investigations into fuels and draught, with reference to combustion, will be a feature of the course. The plan of study has not yet been fully marked out; but a

standing committee of the Faculty, consisting of the professors chiefly concerned, will give their attention, throughout the year, to the further development of this department, which, it is believed, will add much to the strength and usefulness of the school.

LIBRARIES.

The several libraries of the Institute have received considerable additions during the year, both by purchase, especially in the departments of history, literature, and political economy, and by the gift, from Mrs. President Rogers, of very large and very valuable collections of books and pamphlets in physics, mathematics, chemistry, geology, and natural history, from her husband's library, embracing several extensive series of scientific journals and reviews. It is hoped that, during the present year, Mr. Clement W. Andrews, of the chemical department, will be able to carry out the plan, which was last year conceived and undertaken, of making a general catalogue, that should embrace all the books of all the departments. Down to this time each department has had its own library and catalogue, but there has been no single, central place of reference, where it could be quickly ascertained whether a book were in any of the department libraries, and, if so, in which. Mr. Andrews undertook the labor of the general catalogue, at the close of the last school year; but his appointment, by the Treasury Department, to investigate the testing of sugars by the polariscope, at the more important ports of the United States, occupied the entire summer, and led to the postponement of this much-needed work.

I may add that the libraries of the Institute of Technology are, considering the general poverty of means which has been experienced throughout its entire history, of very great value. Even when the school was at the lowest ebb

in its finances, the subscriptions of the Institute to scientific and technical journals and periodicals, in almost every department, and almost the world over, were still maintained; and the result has been a very extraordinary collection of this all-important class of scientific and technical literature.

Each separate department of the Institute maintains its own library, at, of course, the expense of a certain amount of duplication, but with the inestimable advantage of inducing the freest and easiest possible use of the books by the students. The following table gives the results of the first approximate count made by Mr. Andrews, for the purpose of the contemplated catalogue:—

Chemical Department	3,200
English and Political Economy	2,700
Physics	1,850
Geological	800
Civil Engineering	1,050
General	900
Biological	720
Mining Engineering	700
Mechanical Engineering	540
Architectural	470
Margaret Cheney Reading-room	410
Total	13,340

STUDENT PUBLICATIONS.

During the past year the students of the Institute, upon their own motion, established two journals, intended to exhibit, in a serious manner, portions of the work done in the Institute.

The first of these journals, known as the *Technology Quarterly*, has passed through a year of trial, and the first number for the current year has already appeared. This journal is conducted by a board of editors, chosen from the two upper classes, having their own treasurer, business

manager, and advertising agent. At the request of the students, an advisory committee of the Faculty was established as one of the standing committees of that body, for the purpose of conferring with and assisting the editors in the large and difficult work which they have undertaken.

The *Quarterly* is intended to embrace the results of a portion of the original investigations conducted at the Institute by students, as well as by members of the staff of instruction; articles descriptive of new processes and methods, and other matters of scientific or technical importance, contributed by the Alumni, as well as from the Institute; reports and notes of Institute lecture courses on special subjects; and essays of a somewhat varied character. It will thus exhibit the tendency and scope of the more advanced work of the school.

The other journal referred to as established by the students during the past year is known as the *Technology Architectural Review*, conducted by the members of the department of Architecture, with the assistance of an advisory board, consisting of eminent architects in professional practice. The prospectus of this *Review* contemplates the issue of eight numbers yearly, each number comprising four or more large folio plates, exhibiting the original work of the students of the department. The seven numbers already issued have been of unexpected interest and value, and the enterprise has received cordial and even enthusiastic recognition from many of the most eminent architects of the country.

MARGARET CHENEY ROOM.

In addition to the various gifts which have been noted in connection with the several courses of study, the Margaret Cheney Reading-room, for women students, has received from the friends of the Institute, or from the especial friends of the higher education of women, several

valuable presents the past year. Foremost among them is the portrait of Mrs. Ellen H. Richards, the first woman graduate of the Institute of Technology, and, since 1878, an instructor in this school. This picture, the work of Miss Ellen Hale, was presented to the Institute, on behalf of an unknown friend, by Miss Ellen Frothingham and Miss Abby W. May. Other valuable gifts to the Margaret Cheney Room have been made by Miss Anna C. Lowell, Mrs. Edna D. Cheney, and Mrs. Mary L. Williams.

NEW BOILERS.

In addition to the numerous changes and additions of the year, which have already been recited, should be mentioned the introduction into the Rogers Building of new sectional tubular boilers, by the Babcock-Wilcox Company, of over two hundred horse-power, to take the place of two small boilers, of perhaps thirty horse-power each, which were put in when the building was erected, and which, having been in use for twenty years, have become thoroughly worn out. The new boilers, it will be observed, not only replace the worn-out old ones, but largely increase the steam-power at the disposal of the Institute, an increase rendered necessary by the rapid addition of machinery in the departments of Mechanical Engineering and Electrical Engineering.

Partly in consequence of this increase of boiler power, and partly with a view to avoid the effects of such a snow blockade as was experienced last winter, additional coal vaults, of the capacity of sixty tons, were constructed at the beginning of the present season.

THE FINANCIAL CONDITION OF THE INSTITUTE OF TECHNOLOGY.

In my report of last year, I recited the action taken by the Legislature in appropriating $100,000 for the Institut :

of Technology, conditioned upon the establishment of twenty free scholarships; and stated the reasons which, to my mind, made it undesirable to accept this grant thus conditioned. Under instructions from the Corporation, at its December meeting, I presented to the appropriate committees of the General Court of Massachusetts, on its assembling in January, the considerations which favored a more liberal policy on the part of the Commonwealth toward this institution. The reception accorded by these committees to the views presented, the cordial recognition of the work done by this school in the past, and the good wishes of the committees for the future of the school, were most gratifying and encouraging. An appropriation of $100,000, without conditions, in addition to the sum previously appropriated, was favorably reported by the committees of the House and of the Senate, and was passed by large majorities in both branches. A copy of the act, and also of the act of 1887, will be found appended to this report.

The relief to the finances of the Institute obtained through this free grant of $100,000 has been very great. It has cleared the air around us. It has given fresh hope and courage to the Faculty of the school; and has strengthened the administration at a vital point. At the same time, the establishment of the free scholarships, under the State grant of the previous year, while of no pecuniary advantage to the school, has already been the means of enabling several highly deserving young men to continue their studies in the school, who, otherwise, would have been obliged to withdraw. Of the twenty scholarships provided by the act of 1887, ten were opened at the beginning of the present school year, and the other ten will be established in season for the school year 1889–90, after the second payment by the State, on this account.

In addition to the $100,000, stated in my last report to have been raised chiefly through the exertions of Mr.

Endicott, by subscription from the friends of the school, $30,000 have been since raised toward a second $100,000 by the same indefatigable friend of this school and of every good word and work. It is earnestly hoped that the financial troubles of the times will not interfere with the efforts to complete this subscription, during the current year.

During the last session of the Legislature, another act affecting the finances of the school was passed upon the petition of this Corporation, viz., Chapter 72 of the Acts and Resolves of 1888, authorizing the Institute to hold real and personal estate to an amount of which the clear annual income shall be $100,000, to be devoted exclusively to the purposes and objects set forth in an act of incorporation and the acts in addition thereto. The previous income limit, fixed by statute, had been $30,000. That income has not yet been reached; but the recent experiences of Cornell University in being precluded from receiving a large bequest, by reason of a property limit in its charter, seemed to render it the duty of the Corporation to take the action which has been recited.

OBITUARY.

My last word is a sad one. During the year this school, like many another institution, has sustained a great and touching loss, in the death of one who had been for sixteen years a member of its Board of Trust. What land is not full of his good works? What is that kind of charitable or philanthropic effort to which he did not freely contribute by counsel, cheer, and practical assistance? The sun never set upon his beneficence, for he followed humanity around the world, to find its occasions of greatest need; and no appeal in that sacred name ever fell unheard and unheeded upon the ear of Samuel D. Warren.

Resolved, That there be allowed and paid out of the treasury of the Commonwealth the sum of one hundred thousand dollars to the corporation of the Massachusetts Institute of Technology, in the manner following: An instalment of fifty thousand dollars on the first day of December in the present year, and a final instalment of fifty thousand dollars on the first day of December in the year eighteen hundred and eighty-eight; said sums to be applied to the purposes of the Institute. And in consideration of this grant said Institute shall establish and maintain twenty free scholarships, and each senatorial district in this Commonwealth shall once in eight years, in such alternate order as the Board of Education shall at the time of the first apportionment of said scholarships determine by lot, be entitled to one scholarship for a period of four years, to be awarded to such candidates as shall be found upon examination to possess the qualifications fixed for the admission of students to said Institute, and who shall be selected by the Board of Education; preference in the award being given to qualified candidates otherwise unable to bear the expense of tuition. In case no candidate appears from a senatorial district, then a candidate may be selected from the State at large to fill such vacancy, who may continue to hold the scholarship annually until a candidate is presented from the senatorial district unrepresented, who shall then be awarded the scholarship for the balance of the time for which said district would originally have been entitled to its benefit. In case a vacancy occurs in any senatorial district after an appointment has been made, then a candidate from the same district shall be selected for the balance of the time for which said district is entitled to its benefit, or in the event of no such candidate appearing, from the State at large, upon the conditions previously set forth: *provided*, that said corporation shall secure, prior to the first payment above authorized, a further sum of one hundred thousand dollars in addition to the funds now held by it and to be applied to the purposes of the said Institute, and shall present satisfactory evidence thereof to the Auditor of the Commonwealth. [*Approved June* 16, 1887.]

Resolved, That there be allowed and paid out of the treasury of the Commonwealth, the sum of one hundred thousand dollars to the corporation of the Massachusetts Institute of Technology, in addition to the sum authorized to be paid by chapter one hundred and three of the resolves of the year eighteen hundred and eighty-seven, to be applied to the purposes of said Institute; *provided, however*, that this grant is made subject to, and conditioned upon, the establishment and maintenance of the scholarships provided for by chapter one hundred and three of the resolves of the year eighteen hundred and eighty-seven; and *provided, further*, that fifty thousand dollars of the aforesaid sum shall be paid during the year eighteen hundred and eighty-nine, and fifty thousand dollars during the year eighteen hundred and ninety. *Approved May* 23, 1888.]

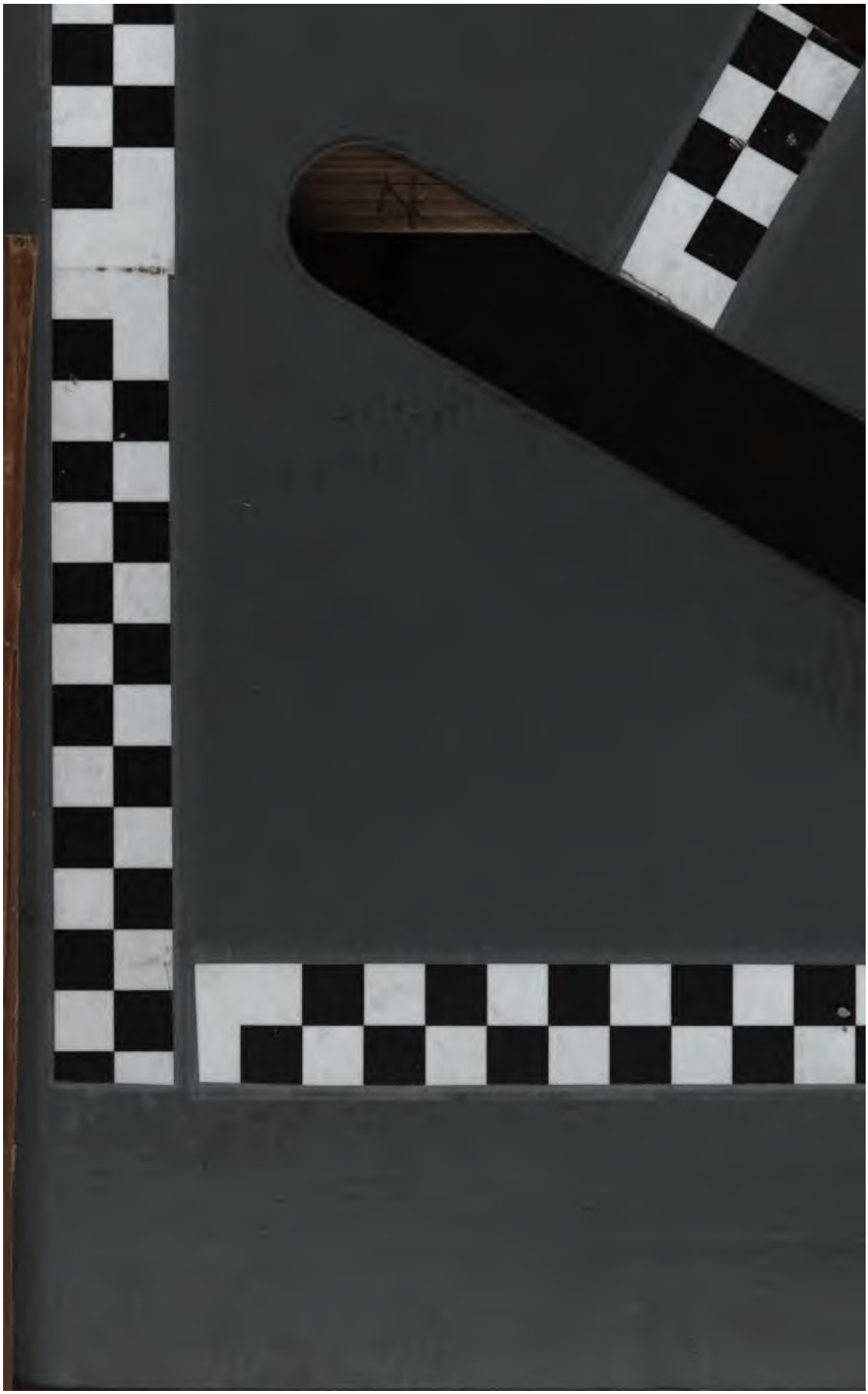
[CHAP. 72.]

AN ACT TO AUTHORIZE THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY TO HOLD ADDITIONAL REAL AND PERSONAL ESTATE.

Be it enacted, etc., as follows:

SECTION 1. Section one of chapter two hundred and twenty of the acts of the year eighteen hundred and sixty-five is hereby amended to read as follows: The Massachusetts Institute of Technology is hereby authorized to hold real and personal estate to an amount of which the clear annual income shall be one hundred thousand dollars to be devoted exclusively to the purposes and objects set forth in its act of incorporation and all acts in addition thereto.

SECT. 2. This Act shall take effect upon its passage. [*Approved February* 29, 1888.]



143

ANNUAL REPORT

OF THE

PRESIDENT AND TREASURER

OF THE

MASSACHUSETTS

INSTITUTE OF TECHNOLOGY,

DEC. 11, 1889.

BOSTON:
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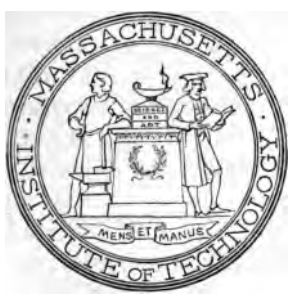

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ALEXANDER H. RICE. M. DENMAN ROSS.
FRANCIS A. WALKER.

To the Corporation of the Massachusetts Institute of Technology:

The present situation of the Institute of Technology is one which awakens in the minds of its friends mingled feelings of rejoicing and of apprehension. On the one hand, we have passed through another year of the highest prosperity, as regards the current work of the school. There has been a great gain in attendance, even over the large numbers of previous years, so that we have now nine hundred scholars, fully told. Those who have thus come to us from all parts of the country, and even from foreign lands, have been found better prepared than ever before to take up their work here with success. The instructing staff has been strengthened; a new building of the highest type has been erected, giving us engineering laboratories of extraordinary extent and completeness; and additional apparatus and machinery have been supplied, in the last twelve months, to an extent which might serve as the total equipment of many a school of applied science. The courses have been broadened, while opportunities for selection of studies and for a higher specialization of technical work have been afforded in greater measure. The spirit of the school has risen, alike among pupils and teachers; the sphere of its influence has widened; the prestige of its diploma is markedly increasing from year to year. So that it may safely be said that never did the Institute of Technology so fully justify its foundation and all the disinterested efforts which have been put forth for its maintenance and enlargement, as to-day; nor were its means of usefulness ever so great.

On the other hand, it is a source of deep regret, and, as I said, of grave apprehension, that the school, at the end of twenty-four years, is still, after all that has most generously been contributed towards its immediate needs by its many friends, virtually unendowed; and is thus without the resources which are needed to secure it from the occurrence of evil fortune directed against itself, or from the effects of financial disaster in the community which it was specially intended to serve. Of the $203,500 which was absorbed during the past year by the current expenses of the school, not less than $158,000, or seventy-eight per cent, was provided by the fees of students; while but little more than $25,000 was derived from the income of invested funds. Such a dependence of a college of the first rank upon tuition fees is altogether unknown among the educational institutions of the United States, and is itself a source of acute danger. A school that is doing the work which the Institute of Technology is carrying forward, amid general approval and with increasing success, ought not to be left in such a questionable and even perilous position. Many institutions, with only one half or one third our number of students, have twice or thrice the amount of our permanent funds.

Had we remained a small school, as we were ten years ago, we should now be moderately well endowed. The great, I might say the overwhelming, increase in attendance upon our courses has not been of our own seeking. It has come as the proper result of the wisdom of the founders of the Institute, and of the energy and self-sacrifice with which its work has been carried on from humble beginnings. The vast majority of those who have resorted to our halls and laboratories have come to us because they thought to find here something which they could not look for elsewhere. In most cases they would not have gone to institutions of a different character had we denied them admission. The needs of the Institute have become so

great, because it was itself so much needed. The very success with which it has fulfilled its part in the educational system of the country has been the cause of its own urgent necessities. Our problem now is to make good what has been so well done; to secure in permanence what we have so fortunately gained. The Institute of Technology needs two millions of dollars to place it on an assured foundation; and it would even then be less fully endowed, relatively to its work and to its needs, than are most of the colleges of the country.

But it is not alone for the permanent endowment of the Institute that additional funds are immediately required. The current expenses of the school are now only met by economies which prevent the proper expansion of its activity over the whole field of its possible usefulness. The salaries we pay our professors and other members of the corps of instruction are cruelly inadequate to the service they render. From lack of means we have to deny ourselves many opportunities for undertaking work which is greatly needed by the community. In the department of Industrial Chemistry alone we ought to be able to expend ten thousand dollars a year more than we now have for that purpose; and could we do so, the return to the people of Massachusetts and New England in the enhanced productiveness of their industries, within a few years, could not fail to be an hundred-fold. In many other departments we are only awaiting assurance of pecuniary support, to undertake work of instruction and of research which would be of great advantage to the Commonwealth and the country.

Doubtless our poverty was, for a while, a good thing, just as straitness of means is generally fortunate for a young man; but the full time has come when the Institute of Technology, having now an honorable history, a distinct constituency, a settled purpose, a well-outlined field of work, a Corporation sympathetic with that purpose and

mission, a Faculty able, devoted, and thoroughly organized to make use of all the means that may be placed at their disposal, may rightfully appeal to the friends of scientific education, and even more emphatically to all who are interested in the industrial development of the country, to give money without grudging, without stinting, and without fear, to enable this school at once to do its whole work in the largest, boldest, strongest manner possible.

THE NEW ENGINEERING BUILDING.

Six years ago, the painfully crowded condition of the Rogers Building led the Corporation of the Institute, even though the financial means for the purpose were not at the time forthcoming, to undertake the construction of the building which stands on the corner of Clarendon and Boylston Streets, since then known as the New Building. The large expense attendant on its erection and equipment, amounting to more than $200,000, was unhesitatingly incurred by the Corporation, in the belief that the same causes which were bringing students to our doors in such rapidly increasing numbers, could not fail to furnish, sooner or later, the resources necessary to provide for their instruction. Probably the Corporation would not have been so confident in this matter, had the Institute had its seat in another place. But the splendid record of Boston's munificence and the frequent experience of the generosity of the special friends of the Institute inspired the Corporation with the courage required for making so large a draft upon the future.

The debts of 1883 are now all discharged, thanks to the bounty of our fellow-citizens and to the Legislature of the Commonwealth. But the problem of that time has again recurred, in crowded halls and laboratories; and, since May of last year, the Executive Committee have been busily concerned with the question what should be done,

not only to provide accommodation for the students actually at our doors, but also to make room for further growth.

By authority of the Corporation, the Executive Committee, in May and June of 1888, purchased 19,240 square feet of land on Trinity Place, opposite the extension of the Museum of Fine Arts, at a cost of $76,315.69; and here, in May of the present year, the erection of a new building was begun.

The question, what kind of a structure should be undertaken, was made, of course, largely to depend on the prior question, what departments of the school should be in view in drawing the plans. Regarding this there could not long be doubt. The department of Mechanical Engineering had, owing to its remarkable growth, alike in the number of students and in the apparatus and machinery required for instruction, become greatly crowded, even before the increase of last year. The prospect of a still further addition to the body of students taking this course, together with the desire of Prof. Lanza to add largely to his equipment, pointed out this as eminently the department to be provided for in the new structure. In the basement of the Rogers Building it could never grow beyond its present limits; and, no matter what departments might move out of the rooms on the floors above, the space thus to be cleared could not answer the special purposes of the mechanical engineering laboratories. Moreover, the Rogers Building was not constructed with reference to the use of heavy machinery or to the employment of power; and great inconvenience has been occasioned, in the past, by the jarring and shaking of its floors and walls. It was therefore the first point settled, in the deliberations over the proposed building, that the Mechanical Engineering department should go there.

This having been determined upon, it seemed most fit that the Civil Engineering department should go to that

building, also, as having much in common with the department of Mechanical Engineering.

The building, as contemplated in the plans drawn within the Institute, and as now virtually completed, at a cost of about $110,000, including equipment and new apparatus, occupies an area upon the ground of 52 feet by 148 feet, and contains six stories, apportioned as follows: —

The two lower floors are entirely devoted to the engineering laboratories; the next two above are allotted to drawing rooms and recitation rooms for the Mechanical Engineering department; while the two upper floors are mainly devoted to drawing rooms and recitation rooms for the Civil Engineering department.

The building was designed with special reference to the uses to which it is to be devoted. It is, in its general plan, an example of what may be called modern mill architecture, although, in order to fulfil the requirements of the laboratories, the foundations, and also the beams, columns, and walls of the lower stories, have been made of extraordinary strength, far beyond the requirements of a factory. The steam used for heating, and also that used for power, is obtained from the boilers in the basement of the Rogers Building, whence it is brought, through a six-inch pipe, laid under the street, a distance of about one thousand feet.

The heating system, which was designed by Mr. Woodbridge, our instructor in heating and ventilation, is partly indirect and partly direct, the ventilation being produced by a Sturtevant blower, acting in connection with the indirect portion of the heating system.

It will be noticed that the laboratories have been spoken of as the engineering laboratories, instead of being called, as formerly, the laboratories of applied mechanics and of mechanical engineering. This change of name is merely a consequence of the natural development of all the engineering departments of the school, as will be made plain by the following considerations: —

First. The subjects of mechanism, thermo-dynamics, and steam engineering, which were formerly regarded as exclusively mechanical engineering studies, now form an essential part of the courses of mechanical engineering, electrical engineering, chemical engineering, and of two of the options of mining engineering; while mechanism has also been introduced into the course of civil engineering. These subjects may, therefore, be said to be general engineering subjects.

Second. The work in hydraulics and hydraulic motors, formerly given to the mechanical engineering students by instructors in their own department, is now to be conducted by Prof. Porter, of the Civil Engineering department, this being a step in the line of the modern idea of specialization, causing all work upon any one subject to be given by one and the same instructor to all students, whatever their course.

Third. These laboratories are really an aggregation of the following, viz.: —

(*a.*) A laboratory for testing the strength of materials.

(*b.*) A steam laboratory.

(*c.*) An hydraulic laboratory.

(*d.*) A laboratory for a great variety of engineering tests and experiments, not yet sufficiently differentiated to be characterized and classified.

Next, as to the general arrangement of the laboratories, and the additional facilities and apparatus provided.

The floor space of the laboratories has been increased from 5,550 square feet, as in the Rogers Building, to about 13,900 square feet, thus rendering it possible to carry on the work with the 190 students, who are to be accommodated in these laboratories during the second term of the present school year, and also providing for a certain amount of future growth.

By way of new apparatus the most important addition is that of a 150-horse-power triple-expansion engine, of the Reynolds-Corliss type, with cylinders 9 inches, 16 inches, and 24 inches, by 30-inch stroke, built specially for the Institute by Messrs. E. P. Allis & Co., of Milwaukee, Wis. It is so constructed that it can be run either single, compound, or triple, and with every possible variety of combinations of the cylinders.

The fact that this is the first triple-expansion engine of a practical size that has ever been arranged for experimental purposes, will enable this laboratory to take a leading position in experimental investigations in steam engineering, and to perform such work for the triple-expansion engine as was done in 1874 by the United States naval engineers for the compound engine, and also to extend to the triple engine the line of research followed out by Hirn, Hallauer, and others, with simple engines.

The next most important addition is that of an hydraulic tank, 5 feet in diameter and 27 feet high, and a stand-pipe 10 inches in diameter and about 85 feet high, which renders possible the development of a large amount of experimental work upon the flow of water through orifices and mouth-pieces and in pipes. Besides these, there are added some other pieces of apparatus, among which may be mentioned a complete set of Westinghouse air-brake apparatus, and a machine for testing the effect of repeated bending upon the elasticity of iron and steel.

Of the drawing room floors the lowest contains a drawing room for the second-year class in mechanical engineering, extending from the front of the building a distance of ninety-six feet towards the rear, while the next floor above contains an equally large drawing room for the third and fourth years' classes in mechanical engineering. The drawing room floor space is thus 9,600 square feet, as against 7,170 square feet, as in the Rogers Building. The remaining portions of these floors are occupied by five

recitation rooms, the largest of which will accommodate sixty students.

The two upper floors are, as has been said, mainly devoted to drawing rooms and recitation rooms for the Civil Engineering department ; on the lower of these two floors, however, a room, 40 feet by 24 feet, is set apart to contain the engineering library and reading room, which will be formed by combining the libraries of mechanical and of civil engineering, comprising together about 1,600 volumes. The engineering library will be in regular receipt of a very large number of engineering journals and periodicals from many countries.

THE GRADUATING CLASS.

The last school year closed fortunately. The class of 1889 graduated on the 28th of May. Of the eighty students of the fourth year, who were candidates for the degree of Bachelor of Science, seventy-five were admitted to that grade by your authority, upon the recommendation of the Faculty.

THE NEW YEAR.

The opening of the academic year 1889–90 witnessed a still further addition to our lists. The number of students in the School of Industrial Science, as by the Catalogue recently issued, is 909, against 827 reported last year, an increase of 82.

The following table exhibits the number of students in the School of Industrial Science each year, from the opening of the Institute to the present time :—

Year.	No. of Students.	Year.	No. of Students.
1865–66	72	1878–79	188
1866–67	137	1879–80	203
1867–68	167	1880–81	253
1868–69	172	1881–82	302
1869–70	206	1882–83	368
1870–71	224	1883–84	443
1871–72	261	1884–85	579
1872–73	348	1885–86	609
1873–74	276	1886–87	637
1874–75	248	1887–88	720
1875–76	255	1888–89	827
1876–77	215	1889–90	909
1877–78	194		

STUDENTS BY CLASSES.

The aggregate number of students for 1889–90 is divided among the several classes as follows: —

Graduate students, candidates for advanced degrees	3
Regular students, Fourth Year	110
" " Third Year	130
" " Second Year	148
" " First Year	261
Special students	257
Total	909

Assigning the special students to classes according to the predominant studies pursued by them, we reach the following statement of the division of the whole body among the several years: —

Class.	Regular.	Special.	Total.
Graduates of the M. I. T.	3	5	8
Fourth Year	110	25	135
Third Year	130	38	168
Second Year	148	129	277
First Year	261	60	321
	652	257	909

STATISTICS OF EXAMINATIONS.

Of the 909 students of the present year, 352 were not connected with the school in 1888–89.

Twelve had been connected with the Institute at some previous time, and returned to resume their places in the school; 17 were admitted provisionally, without examination; 50 were admitted on the presentation of diplomas from other institutions.

Excluding from consideration those who were admitted but have not, in fact, entered the school, the following was the result of the examinations held: —

Admitted clear		189
" on one condition	44	
" " two conditions	25	
" " three "	11	
" " more than three conditions	4	
	—	84
Rejected		60
		333

EXAMINATIONS AT DISTANT POINTS.

In addition to the entrance examinations held in Boston in June and September, 1888, examinations were also conducted, in June, at Chicago, Cincinnati, Kansas City, New York, Philadelphia, Pittsburg, San Francisco, St. Louis, St. Paul, and Washington.

Thirty-five States of the Union, besides the District of Columbia, are represented on our lists of students; of the total number of 909, including special students, 533 are from Massachusetts, or 58.6 per cent of the whole; 114 are from other New England States; 262 from outside New England, of whom 22 are from foreign countries.

The following table shows the number of students of each specified class for each State or foreign country: —

State.	Candidates for Advanced Degrees.	Fourth Year.	Third Year.	Second Year.	First Year.	All Regular Students.	Special Students.	Total.
Alabama	....	..	...	...	...	...	1	1
Arkansas	....	..	2	...	...	2	...	2
California	....	2	...	3	1	6	4	10
Colorado	....	.	...	2	1	3	3	6
Connecticut	....	3	9	4	10	26	10	36
Dist. Columbia	....	..	1	1	...	2	7	9
Florida	....	..	1	. .	1	2	...	2
Georgia	....	..	...	1	...	1	...	1
Illinois	....	4	7	8	8	27	6	33
Indiana	...	..	1	...	...	1	2	3
Iowa	....	1	...	1	1	3	1	4
Kentucky	....	2	...	1	1	4	...	4
Louisiana	....	..	...	1	2	3	1	4
Maine	....	1	4	3	11	19	11	30
Maryland	....	1	...	1	1	3	1	4
Massachusetts	2	66	73	84	160	385	148	533
Michigan	....	..	3	2	3	8	5	13
Minnesota	....	2	...	3	3	8	2	10
Missouri	....	..	...	1	2	3	5	8
Nebraska	....	1	...	...	...	1	...	1
N. Hampshire	....	5	3	4	4	16	5	21
New Jersey	....	2	...	2	6	10	3	13
New York	....	2	8	2	6	18	7	25
No. Carolina	....	..	...	1	...	1	1	2
Ohio	....	5	3	3	12	23	12	35
Oregon	....	..	1	...	1	2	...	2
Pennsylvania	1	1	2	2	8	14	9	23
Rhode Island	....	6	3	3	7	19	3	22
So. Carolina	....	1	...	...	...	1	...	1
South Dakota	....	1	. .	...	...	1	...	1
Tennessee	....	..	1	2	...	3	2	5
Vermont	....	1	...	...	...	1	3	4
Virginia	....	...	1	2	2	5	1	6
Washington	....	...	1	1	...	2	...	2
West Virginia	....	...	...	...	1	1	1	2
Wisconsin	....	2	2	3	2	9	1	9
Foreign Countries.								
Brazil	....	...	...	1	...	1	1	2
Bulgaria	....	...	...	1	...	1	...	1
Colombia	....	...	...	...	1	1	...	1
France	....	...	...	...	1	1	...	1
Guatemala	....	...	...	1	...	1	...	1
Hawaian Isl'ds	....	...	...	1	...	1	...	1
Ireland	....	...	1	...	...	1	...	1
Japan	....	...	...	...	1	1	...	1
Mexico	....	...	...	...	1	1	...	1
N. Brunswick	....	...	...	1	...	1	...	1
Nova Scotia	....	...	...	...	2	2	...	2
Peru	....	...	...	...	...	...	1	1
Porto Rico	....	...	1	...	1	2	...	2
Prov. Ontario	....	1	...	...	...	1	...	1
Prov. Quebec	....	...	1	...	...	1	...	1
Scotland	....	...	...	1	...	1	...	1
Trinidad	....	...	...	...	...	...	1	1
Turkey	....	...	1	1	...	2	...	2
	3	110	130	148	261	652	257	909

RESIDENCE OF MASSACHUSETTS STUDENTS.

It has been said that 58.6 per cent of our students are from Massachusetts. All the counties of the State, except the small counties of Dukes and Nantucket, send students to the Institute. Ninety-seven cities and towns are reported on the lists. The first column of the following table shows the number of cities and towns in each county sending pupils to the Institute; the second column gives the aggregate number from each county. It appears that

Suffolk sends us 197 pupils; Middlesex comes next, with 160; Essex third, with 50; Norfolk fourth, with 43.

County.	No. of Towns.	No. of Students.	County.	No. of Towns.	No. of Students.
Barnstable . .	2	4	Hampden . .	4	11
Berkshire . . .	2	2	Middlesex . .	28	160
Bristol	6	22	Norfolk . . .	16	43
Essex	14	50	Plymouth . .	10	20
Franklin . . .	1	2	Suffolk . . .	3	197
Hampshire . .	1	2	Worcester . .	10	20
	26	82	Total . . .	97	533

The following is a list of the towns, twenty-five in number, which send four or more scholars to the Institute: —

Boston 180	Lynn 9	Melrose 6
Newton . . . 33	Salem 8	New Bedford . . 5
Cambridge . . . 24	Taunton . . . 8	Belmont . . . 4
Chelsea 16	Waltham . . . 8	Dedham . . . 4
Brookline . . . 14	Fall River . . . 7	Gloucester . . . 4
Lowell 13	Fitchburg . . . 7	Holyoke . . . 4
Newburyport . . 11	Framingham . . 6	Medford . . . 4
Somerville . . . 11	Lawrence . . . 6	Winchester . . 4
Malden 10		

PROPORTION OF OLD AND OF NEW STUDENTS.

The following table exhibits, for each year since 1882, the distribution of the total number of students among two classes: first, those students whose names are found upon the Catalogue of the year preceding; and secondly, those students whose names appear as new names upon the Catalogue of the year to which the statement relates: —

Year.	(1) Total No. of Students.	(2) No. of Students in the Catalogue of the previous year who remain in the Institute.	(3) No. of New Students entering before issue of Catalogue.	(4) Of those in column (3) the following number are regular first-year Students.	(5) No. of New Students not of the regular first-year class.
1882–83	368	173	195	114	81
1883–84	443	231	212	140	72
1884–85	579	311	268	186	82
1885–86	609	369	240	177	63
1886–87	637	379	258	190	68
1887–88	720	396	324	229	95
1888–89	827	465	362	245	117
1889–90	909	557	352	255*	97

It appears from the foregoing that the number of students remaining over has been increased by 92, while the number registered for the first time is smaller by 10, making the net gain, as previously stated, 82.

AGES OF STUDENTS ON ENTRANCE.

The next table exhibits the ages of our students upon entrance. The regular students of the first-year class number 261. From these we should except 6 cases of students of unusual ages. These deductions leave 256 as the number of students whose ages have been made the subject of computation.

The results appear in the following table, in comparison with the corresponding results for 1888–89: —

* In addition, 6 students are repeating the first year.

Period of Life.	1888–89.		1889–90.	
	Half-Year Groups.	Yearly Groups.	Half-Year Groups.	Yearly Groups.
16 to 16½ years	3	..	1	..
16½ to 17 years	10	13	9	10
17 to 17½ years	23	..	26	..
17½ to 18 years	43	66	49	75
18 to 18½ years	53	..	58	..
18½ to 19 years	39	92	43	101
19 to 19½ years	25	..	30	..
19½ to 20 years	19	44	10	40
20 to 20½ years	16	..	12	..
20½ to 21 years	6	22	10	22
21 to 22 years	9	9	7	7
	246	246	255	255

From the foregoing tables it appears that the average age of the 255 students taken for this comparison, the present year, is 222.4 months, or 18 years 6 months and 12 days. This compares with the corresponding figures relating to previous entering classes as follows: —

	Av. Age in Months.
Class of 1889	218.53
Class of 1890	219.91
Class of 1891	221.55
Class of 1892	223.50
Class of 1893	222.40

In this connection it may be interesting to note the ages at graduation of the class leaving us in May. The 75 members of the class were distributed among the several periods of life, as follows: —

Under 20	2	Between 22 and 23	19
Between 20 and 20½	5	" 23 and 24	6
" 20½ and 21	12	" 24 and over	8
" 21 and 21½	12		75
" 21½ and 22	11		

PROPORTION OF REGULAR AND OF SPECIAL STUDENTS.

The following table exhibits both the absolute number of regular and of special students, as by the Catalogue of each successive year since 1882, and the proportion existing between these two classes: —

Year.	No. of Regular Students.	No. of Special Students.	Total No. of Students.	Percentage.	
				Regular.	Special.
				Per cent.	Per cent.
1882–83	*219	149	368	60	40
1883–84	272	171	443	61	39
1884–85	368	211	579	64	36
1885–86	415	194	609	68	32
1886–87	442	195	637	69	31
1887–88	520	200	720	72	28
1888–89	590	237	827	71	29
1889–90	652	257	909	72	28

WOMEN AS STUDENTS IN THE INSTITUTE.

The number of women pursuing courses with us last year was 33; this year it is the same. Of this number, 7 are graduates of colleges. Of the total number, 5 are regular students of the fourth year; 2 of the third year; 3 of the second year; 23 are special students. Of the 10 regular students of the upper classes, 1 takes Course IV., architecture; 4 Course V., chemistry; 4 Course VII., natural history; 1 Course IX., the general course. Of the special students, 9 devote themselves chiefly to chemistry and physics; 9 chiefly to biology and allied subjects; 4 to mathematics; and 1 to architecture.

GRADUATES OF OTHER COLLEGES.

Fifty graduates of institutions conferring degrees are included in our list of students for the present year. Of these, 8 are our own graduates, of whom 3 are pursuing studies as candidates for advanced degrees. Forty-three

* Including one who is also a graduate of the Institute of Technology.

are graduates of other institutions, pursuing courses of study with us, either as regular or as special students. Of these, 10 are graduates of Harvard University, 5 each of Brown University and Yale University, 4 of Boston University, 3 of Amherst College, while one comes from each of the following institutions: University of Minnesota, Oregon State University, Oberlin College, Hobart, Bowdoin, Rutgers, Boston College, Swarthmore, Pennsylvania State College, Bryn Mawr, United States Military Academy, Holy Cross College, Trinity, Robert College, Georgetown College, and Vassar.

Of the 47, not candidates for advanced degrees here, 8 are regular students of the fourth year, — 2 in civil engineering, 3 in mechanical engineering, 1 in archi tecture, and 2 in electrical engineering; 7 are regular students in the third year, — 3 in civil engineering, 3 in electrical engineering, 1 in chemical engineering; 8 are regular students in the second year, — 2 in civil engineering, 1 in mechanical engineering, and 5 in electrical engineering; the remaining 24 are special students.

THE COURSES OF INSTRUCTION.

The following table presents the number of students in each of the regular courses. It will be seen that this statement relates to the second, third, and fourth years, choice of courses being made only at the end of the first year: —

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Electrical Engineering.	Natural History.	Physics.	General Course.	Chemical Engineering.	Sanitary Engineering.	Total.
4th Year Class . .	26	33	4	5	13	19	3	2	5	..	..	110
3d " " . .	24	37	3	9	11	29	2	2	2	11	..	130
2d " " . .	29	29	7	16	5	43	4	1	5	3	6	148
Total . . .	79	99	14	30	29	91	9	5	12	14	6	388

The following table exhibits the number of persons who have graduated within each of the several courses, at each succeeding year since the first diplomas were conferred: —

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering.	Architecture.	Chemistry.	Metallurgy.	Electrical Engineering.	Natural History.	Physics.	General Courses.	Total.
1868	6	1	6	..	..	..	..	..	..	1	14
1869	2	2	..	..	1	..	..	..	..	..	5
1870	4	2	2	..	1	..	..	..	..	1	10
1871	8	2	5	..	2	..	..	..	..	..	17
1872	3	1	5	..	3	..	..	..	..	..	12
1873	12	2	3	1	7	..	..	..	..	1	26
1874	10	4	1	1	..	..	..	..	..	2	18
1875	10	6	6	1	1	..	..	..	1	2	27
1876	12	9	7	..	5	1	..	2	3	4	43
1877	12	6	8	4	2	..	..	..	..	..	32
1878	8	2	2	3	3	..	..	..	..	1	19
1879	6	8	3	1	3	..	..	1	1	..	23
1880	3	..	3	..	1	..	..	..	..	1	8
1881	3	5	6	3	8	..	..	1	..	2	28
1882	2	5	5	3	6	..	..	1	1	1	24
1883	3	7	4	1	3	..	..	..	..	..	18
1884	5	6	13	..	12	..	..	..	..	..	36
1885	4	6	8	2	4	..	2	..	..	1	27
1886	9	23	7	1	7	..	10	1	..	1	59
1887	10	17	8	1	9	..	8	1	1	3	58
1888	11	25	4	5	10	..	17	3	1	1	77
1889	15	23	5	3	8	..	17	1	1	2	75
Total,	158	162	111	30	96	1	54	11	9	24	656
Deduct names counted twice											2
Net total											654

The special students in the School of Industrial Science cannot be classified systematically; but the following table exhibits the number of special students pursuing each particular branch of study: —

NUMBER OF SPECIAL STUDENTS ATTENDING EXERCISES IN THE FOLLOWING DEPARTMENTS OF STUDY OR PRACTICE.

Architecture	66	Literature	28
Applied Mechanics	31	Mathematics	130
Astronomy	18	Mechanism	38
Biology	17	Mechanics and Acoustics	6
Blowpipe Analysis	6	Mechanical Engineering	11
Chemistry	75	Metallurgy	11
Civil Engineering	16	Military Drill	12
Climatology	3	Mining	3
Commercial Geography	6	Organic Chemistry	8
Drawing	42	Physics	111
Descriptive Geometry	63	Physiology	5
Electricity	2	Political Economy	60
English	14	Political Science	4
French	34	R. R. Management	10
Geology, etc.	21	Spanish	1
German	100	Shop-work	55
Heating and Ventilation	3	Surveying	24
History	14	Theoretical Chemistry	12
Industrial Chemistry	8	Zoölogy	9

Total number of entries, by special students	1,077
Total number of special students	257
Average number of entries	4.2

It may be of interest to note the number of students, either regular or special, pursuing certain leading branches of study, in each of the four years, which are as follows:—

Studies.	First Year.	Second Year.	Third Year.	Fourth Year.	Total.
Mathematics	315	249	140	27	731
Chemistry	306	60	31	28	425
English	272	208	106	8	594
French	258	19	18	6	301
Physics	..	231	160	21	412
German	51	190	131	13	385
Shop-work	..	114	59	43	216

THE CORPS OF INSTRUCTORS.

The Catalogue for 1889–90 shows the number of instructors of all grades, excluding instructors and assistants in the shops, and excluding, also, those persons who are announced as lecturers for the year only, to be 85, against 79 last year.

The following table shows the number of teachers of each recognized grade, exclusive of the department of Mechanic Arts, in each year since 1882:—

Year.	Professors.	Associate Professors.	Assistant Professors.	Instructors.	Assistants.	Total.
1882–83	16	..	3	10	11	40
1883–84	15	..	8	15	10	48
1884–85	14	3	11	15	14	57
1885–86	14	6	7	17	18	62
1886–87	12	7	6	27	17	69
1887–88	13	6	9	30	17	75
1888–89	12	7	10	32	18	79
1889–90	10	12	5	34	23	84

In addition to the teachers thus reported for the present year, three instructors and three assistants are engaged in the shops.

CHANGES IN THE FACULTY AND THE CORPS OF INSTRUCTORS.

The changes occurring within the Faculty during the past year have been in number fewer than has been usual of late; yet those which have taken place are of much importance.

After twenty-three years of active service, in charge of the department of English and History, Prof. William P. Atkinson resigned his connection with the Institute of Technology, at the close of the school year 1888–89. A member of the original staff of the Institute, Prof. Atkinson has been the teacher of every student who has gradu-

ated from the school. His genial ways and cordial, unaffected interest in young men have to an unusual degree made his pupils his friends. At the beginning, no member of the Faculty had a heartier faith than he in the kind of education which the Institute had undertaken to provide; and his pride in the school and his devotion to its interests continued unabated to the end. Prof. Atkinson's lectures were always interesting, and, to students of a decided turn to political and historical study, they were highly suggestive and inspiring.

The following resolution was adopted by the Executive Committee, Feb. 5, 1889: "That, in accepting the resignation of Prof. Atkinson, the Executive Committee desire to convey to him their high appreciation of the disinterested and faithful service he has performed for the Institute during the twenty-three years of his connection with it." No appointment has yet been made to the chair vacated by Prof. Atkinson. The classes hitherto taught by him have been assigned temporarily to Profs. Levermore and Dewey, or have been assumed by Dr. Benjamin Rand, of Harvard University, under an appointment for the present year.

The chair of Modern Languages, made vacant by the death of Prof. Otis, has been filled by the appointment of Dr. Alphonse van Daell, late Director of Modern Languages in the public school system of Boston. Dr. van Daell, a native of Belgium, studied at the College of Saint Servais, in Liège, graduating B. A. in 1864. He subsequently pursued his studies at Louvain, passing examinations in Philosophy and Letters. In 1868 he took the degree Docteur en Droit, at the University of Liège; and in the two following years attended lectures in Paris, Bonn, and Berlin. He came to America in 1873, and taught in private schools until 1876. He was then called to the chair of Modern Languages in Kentucky College, where he remained until 1879, when he moved to Philadelphia, and taught for several years thereafter in private

schools. In 1885 he became instructor in Haverford College, and lecturer in the University of Pennsylvania, which positions he resigned, in 1886, to accept the Directorship of Modern Languages in the Boston High and Latin Schools.

Dr. van Daell's works are: —

(1.) A Monograph on the Study of Modern Languages.

(2.) La Parole Française, a practical introduction for the oral use of the French language.

(3.) Das Deutsche Buch, a similar work in German.

(4.) *Leander's* Träumereien, edited and annotated.

(5.) *Heine's* Harzreise, edited and annotated.

(6.) *Les Mémoires du duc de Saint Simon*, edited and annotated.

The appointment of Prof. van Daell of necessity terminated the provisional engagement of Mr W. C. Dreher, who had been employed for the year 1887–8 and a portion of the year preceding in the instruction of some of the classes relinquished by Prof. Otis.

In consideration of eighteen years of distinguished service in the department of Architectural Design, Associate Prof. Eugene Letang was granted, by the Executive Committee, a leave of absence for the school year 1889–90, which he will pass in Europe. Prof. Letang's classes will be taken, the current year, by Mr. C. Howard Walker, who has so long and with such eminent success taught interior decoration to our classes in architecture. Mr. Ross Turner having, also, gone abroad for the year, Mr. Walker has, in addition, assumed charge of the instruction in sketching and in water color.

The Executive Committee have been so fortunate as to be able to arrange for a course of lectures on Business Law during the second half of the present school year, from Prof. John C. Gray, of the Law School of Harvard University. Prof. Gray gave such a course in the Institute several years ago, to the great gratification of the whole

body of our students and with the best effect. Circumstances have prevented the continuance of that course in subsequent years; but Prof. Gray has consented to give these lectures the present year. The Executive Committee have nearly concluded arrangements through which a course of lectures on the Law of Business, extending through the entire year, will be regularly given hereafter by a distinguished member of the Boston bar.

Assistant Profs. Peabody, Allen, Burton, Dewey, and Levermore have been promoted to the grade of Associate Professor.

Dr. Howard V. Frost, whom we looked to see continue in charge of the Laboratory of General Chemistry, resigned, at the close of the school year, to become the head of the department of Chemical Instruction in the Brooklyn Collegiate and Polytechnic Institute. Dr. Frost's place, in charge of the Laboratory of General Chemistry, has been taken by Mr. Frederic L. Bardwell. Mr. Bardwell filled the position during the two years of Dr. Frost's absence, 1886–88, to the satisfaction of the department. This Laboratory now includes three hundred students. Mr. Bardwell is assisted the current year by Mr. Burns, instructor, and by three assistants.

Assistant Prof. Frederick W. Clark, who had for seven years been Prof. Richards' principal assistant in the department of Mining and Metallurgy, resigned that position at the close of the school year 1888–89, with a view to engaging in business. Prof. Clark has shown himself highly intelligent, active, and versatile, both in class-room instruction and in the work of the laboratory. He has borne a large part of the burden of the Summer School of Mining, and has labored in every way to advance the interests of the Institute.

To the position vacated by Prof. Clark, the Executive Committee appointed Dr. Heinrich O. Hofman, then a Professor in the Mining School of South Dakota. Prof.

Hofman, a native of Heidelberg, received his training at the Gymnasium of that city, and in 1871 entered the University, where he remained two years, pursuing the natural sciences. Thence he went to the Royal Prussian School of Mines, whence he graduated, both as mining engineer and as metallurgist, in 1877, entering the government service as chemist and assistant at the Lautenthal Smelting Works, in the Hartz Mountains. In 1881 Dr. Hofman came to America and engaged in metallurgical work, being employed in Pennsylvania, Missouri, Kansas, Colorado, and in Mexico. In 1885 he became private assistant to Prof. Richards at the Institute of Technology, and in 1886–87, by appointment of the Executive Committee, delivered a course of lectures to our students. In the autumn of 1887 he was appointed Professor of Metallurgy in the School of Mines in Dakota, where he remained until recalled to the Institute.

Shortly after the opening of the present school year, Mr. James P. Munroe, with a view to engaging in business, resigned the position of Secretary of the Faculty, which he had held with great acceptance. Mr. Munroe graduated in 1882 from the course in Mining Engineering. At the beginning of the next school year he became the assistant of Prof. Richards, then Secretary of the Faculty; and the following year became Registrar under the secretaryship of Prof. Wells. At the commencement of the school year 1884–85 Mr. Munroe assumed the duties of Secretary. During the great enlargement of the school which has since taken place, alike in the number of students, the introduction of new studies, the organization of new courses, and the multiform extension of the work of the Institute, Mr. Munroe has performed an important part. His quick intelligence, his wonderfully retentive memory, his scrupulous fidelity, his thorough knowledge alike of the present situation and of the traditions of the school, have qualified him to be an assistant and an ad-

viser on many questions of great consequence, as well as a faultless administrator in the regular routine of instruction and discipline.

Mr. Munroe's place has been taken for the current year by Dr. Harry W. Tyler, who returned from Germany in September to resume his relations to the school as Instructor in Mathematics. Greatly as his services were needed in that heavily burdened department, it was felt that the position of Secretary to the Faculty was one of such importance as to justify this sacrifice; and Dr. Tyler was accordingly prevailed upon to forego the resumption of his work as an instructor for at least a year, that the office of Secretary might suffer as little as possible through the resignation of Mr. Munroe.

Mr. Frank A. Moore, Junior Instructor in Architecture, having declined reappointment, Mr. Walter H. Kilham, of the Class of 1889, was appointed to his place.

The Assistants for the school year 1889-90 are as follows: Louis E. Levi, Edward C. Holton, William S. Davenport, in General Chemistry; Charles Ferry, James W. Loveland, and James P. Gilbert, in Analytical Chemistry; Frank H. Thorp, in Industrial Chemistry; George L. Heath, in Sanitary Chemistry; Bertrand R. T. Collins, Willard G. Bixby, Franklin W. Hobbs, Lewis H. Kunhardt, in Mechanical Engineering; James H. Stanwood, Frank H. Cilley, Alfred W. French, William E. Mott, in Civil Engineering; Edward Collins, Jr., and Frank A. Laws, in Physics; Arthur B. Frizell and Horace P. Edgett, in Mathematics; Amos E. Woodward, in Geology; Edward S. Hutchins and Frank E. Sanborn, in Descriptive Geometry.

In addition to the regular staff of instruction, the following gentlemen have been appointed lecturers for the current year: John C. Gray, A. M., LL. B., on Business Law; George W. Blodgett, S. B., on Applications of Electricity to Railway Working; Henry M. Howe, A. M.,

S. B., on **Metallurgy**; Charles W. Hinman, S. B., on the **Manufacture of Illuminating Gas**; Walter S. Allen, S. B., on the **Manufacture of Fertilizers**; David A. Gregg, on **Pen and Ink Drawing**; Anthony C. White, S. B., on the **Distribution of Electricity for Commercial Purposes**; Edward Blake, Ph. B., on the Construction and Applications of **Electro-Motors**; Edwin O. Jordan, S. B., on **Biology**.

Including these and the lecturers for the current year, we find the total number of persons engaged in the work of instruction to be 100, distributed among the several departments as follows:—

	Civil Engineering.	Mechanical Eng. and App. Mechanics.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Physics and Elect. Engineering.	Biology, Zoology, etc.	Mineralogy, Geology, and Geography.	English and Political Science.	Language.	Mathematics.	Drawing and Descrip. Geometry.	Mechanic Arts.	Military Tactics.
Professors.....(10)	1	1	1	1	1	1	....	1	....	1	2	....	....	....
Associate Professors (12)	2	2	....	1	1	1	1	....	2	1	1	....	....	....
Assistant Professors (5)	1	....	1	....	1	....	....	1	....	....	....	1	....	....
Instructors.....(37)	1	5	1	3	5	4	1	1	2	3	4	3	3	1
Assistants.....(26)	4	4	....	....	8	2	....	1	....	....	2	2	3	....
Total.....(90)	9	12	3	5	16	8	2	4	4	5	9	6	6	1
Lecturers.....(10)	....	....	1	2	2	3	1	....	1	....	....	....	....	....
Total.....(100)	9	12	4	7	18	11	3	4	5	5	9	6	6	1

SCHOLARSHIPS.

In addition to the ten free scholarships established in 1887, under the grant from the Commonwealth, ten more State scholarships were instituted on the same foundation, last year, making the final number of twenty. Thirteen

students are receiving aid this year, to the extent of a whole or a part of their tuition, from the Richard Perkins fund. The beneficiaries of the Sherwin, Joy, Farnesworth, Mirrless, and Milton (town) scholarships raise the total number to thirty-eight.

In December, 1888, the Trustees under the will of Mrs. Susan H. Swett made over to the Institute the sum of ten thousand dollars, to be set apart as a fund for maintaining a graduate scholarship. This addition to our means of encouraging advanced students at the Institute is most welcome, and cannot fail to be found of great advantage. The Swett scholarship has been awarded for the present year to Mr. Richard Lee Russel, a graduate of the last class from the department of Civil Engineering. With a view to still further promote advanced studies the Corporation have voted that hereafter the income of the James Savage fund shall be used for supporting a graduate scholarship, instead of two undergraduate scholarships, as in the past.

LIBRARIES.

Since the last annual report Mr. Clement W. Andrews has been appointed Librarian of the Institute. His work of cataloguing the several departmental libraries has been carried on through the year under many interruptions. It is hoped that it will be continued the present year to greater advantage. The several libraries have received accessions at about the usual rate, the most important relative gains being in the library of the Architectural department.

SUMMER SCHOOLS.

The summer work in topography, geodesy, and geology, first planned and inaugurated in the summer of 1888, as stated in my last report, was again carried out, and with marked success, in the summer of 1889. The location

chosen for the work was the town of Schoharie, N. Y., and the instructors in attendance were Profs. Swain, Burton, and Niles, and Mr. Whipple of the Class of 1889, all of whom gave their time gratuitously. The school covered a period of between four and five weeks, of which time the greater part was devoted to topographical and geological work, including base line measurements, triangulation, work with the stadia, plane table and barometer, and the preparation of geological maps and sections, all under the direction of Profs. Burton and Niles. The latter portion of the time was devoted to the work of measuring the flow of the Schoharie Creek, under the direction of Prof. Swain. Eleven students were in attendance, all members of the present graduating class. They manifested interest and enthusiasm in the work, and the results of the course were all that could have been expected. The locality chosen was exceptionally favorable for topographical and geological study. It is expected that the school will be again carried on during the coming summer, the experience of the past two years having proved it to be a success in every particular, and to supply a want which could not otherwise be filled.

For the benefit of the students of the mining courses, a summer course in metallurgy was organized in June for the purpose of studying the iron blast furnace under as many conditions as possible. The class devoted the early part of their time to the anthracite furnaces of the Lehigh Valley. Here are to be found the best examples of furnaces designed for making iron with this densest of fuels. The construction of the furnaces, as well as the mode of running them, was studied to great advantage. At Bethlehem, the large plant of the Colebrook furnaces gave an opportunity for observing furnaces running on mixed coke and anthracite, mainly coke. At Steelton, the furnaces were run wholly with coke. Here the class were especially fortunate in having an opportunity to watch a furnace

recover from having been chilled by the Susquehanna flood. Finally, the students visited the magnificent plant of four great coke furnaces, now being erected by the Pennsylvania Steel Company, at Sparrow's Point, Md. Here were to be seen furnaces in four stages of construction, from the earliest to the point of being just ready to go into blast. Aside from the main object under consideration, the party also visited several steel works, iron mines, zinc works, and an anthracite mine; and they are much indebted for generous hospitality received to Mr. Fritz and Mr. Schropp, of Bethlehem; Mr. Thomas, of Hokendauqua; Mr. Goodwin, of the Lehigh Valley Railroad; Major Bent and Mr. Wood, of the Pennsylvania Steel Company; Mr. Eckley B. Coxe, of Drifton. The summer courses in mining and metallurgy will hereafter be arranged to take place on alternate years. The Faculty have not yet decided to make the course compulsory, since this would involve an expense which some of the students might not be able to bear.

Course I. *Civil Engineering.* — No changes of importance have been made in the studies in this course during the past year. The scheme of instruction, as now laid down, appears to be fully satisfactory, and it is not probable that any essential modifications will, for some time, be required. With regard to the assignment of the work of instruction, however, changes have been rendered necessary. The instruction in hydraulics, hitherto given by Prof. Swain, has been transferred to Prof. Porter, who has been relieved from some other work, and who will henceforth devote himself almost exclusively to sanitary and hydraulic engineering, giving the instruction in hydraulics to the students in mechanical and electrical engineering as well as to those in civil engineering. This change, as well as the increased number of students in the department, the large number of other students taking the course in surveying, and the accession of graduate students, has caused a great pressure on the accommodations of the

department and upon its corps of instructors, and has rendered imperative a considerable increase in the number of assistants, which is even now scarcely sufficient to do the work to the best advantage.

In connection with the work in hydraulics, a new and important feature will be the hydraulic laboratory in the engineering building. In designing this laboratory the purpose has been to provide facilities for making all the hydraulic tests and experiments which it is possible to carry on within doors and with small quantities of water. A wrought-iron tank, twenty-seven feet high and five feet in diameter, has already been built, and will be connected with pumps and with a stand-pipe and a supply pipe, both running to the top of the building, thereby rendering available a head of about eighty-five feet. The tank will be provided with apparatus of various kinds, and means will be afforded for measuring the flow through orifices and mouth-pieces, both free and submerged, over weirs and through pipes; and for studying the losses of head under various conditions, the distribution of velocity in pipes and jets, and other problems of interest. It is expected that as the laboratory grows there will be means for testing small motors and meters of various kinds, and for all other similar work. The Swain turbine, now in the mechanical engineering laboratory, will be used, as heretofore, in connection with the hydraulic work. The soil pipe, which serves as an overflow pipe from the stand-pipe and the supply pipe, is also to be provided with appropriate connections to render possible the carrying on of experiments upon the siphonage of traps, and other work relating to the plumbing and drainage of houses, a branch of experiment here attempted for the first time, I believe, in connection with work of instruction.

The instructors in this department are gradually getting their courses into print for the use of the students. During the past year Prof. Allen has had his notes on earth-

work and on railroad curves and location lithographed; and Prof. Swain is this year having almost his entire course on bridges and construction printed in the same manner, thereby much facilitating the work of instruction.

It is scarcely necessary to refer to the disadvantages under which the work of the department has of late been carried on, owing to the lack of needed room. The removal of the department to the engineering building at the close of the present term will afford a relief which has become imperative.

Mention should here be made of the fact that two of last year's graduates in this department, Messrs. S. H. Mildram and R. L. Russel, have returned this year to pursue advanced courses of study and research. Should the attendance of such students continue, it will be imperative to relieve Prof. Swain still further from some of the undergraduate work, by providing further assistants, in order that he may be able to devote more time to the conduct of his graduate classes. Until such provision can be made, it is not desired that the number of such students should be large, nor is it, indeed, expected that it ever will be; but the presence of a few earnest workers, pursuing advanced courses, cannot fail to exert a beneficial influence over the undergraduate students. It is further to be remarked that three graduates in mechanical engineering, Messrs. Cromwell, Davis, and Williston, have this year returned to take up studies in civil engineering. The outfit of the department has this year received no considerable additions beyond those referred to in connection with the hydraulic laboratory. The library, however, has been materially enriched by the addition of a large number of valuable books and pamphlets from the library of the late Edward S. Philbrick, generously presented to the department by Mrs. Philbrick.

Prof. Swain has continued his services as expert engineer to the Board of Railroad Commissioners of Massa-

chusetts, and has made numerous reports to the Board in that time upon the condition of the railroad bridges of the Commonwealth.

Course II. *Mechanical Engineering.* — The most important changes in this course have already been referred to in connection with the statements concerning the new engineering building.

In addition to the above, it may be noted that the publications issuing from the department during the past year are : —

1. A treatise on the "Thermodynamics of the Steam Engine," by Associate Prof. Peabody.

2. A paper on the "Flow of Steam through Orifices," presented to the American Society of Mechanical Engineers by Associate Prof. Peabody, embodying the results of the thesis of Mr. L. H. Kunhardt of the Class of '89.

3. A paper on the "Errors of different Types of Calorimeters," presented to the American Society of Mechanical Engineers by Associate Prof. Peabody, embodying the results of the thesis of Mr. A. L. Williston, of the Class of '89.

During the year a short course of lectures on Naval Architecture was given by Naval Constructor J. J. Woodward, of the United States Navy, to the students taking the marine engineering option. It is hoped to have a somewhat longer course given upon this subject during the present year.

There have been presented to the department during the past year, —

1. A Stratton separator.

2. A set of Crosby safety valves, some of them sectioned, to serve for illustration.

3. A number of blue prints and drawings from different works.

At the middle of the present school year, Mr. S. G. Stephens severs his connection with the Institute in order

to go into business, and the drawing room is to be placed in charge of Instructor E. F. Miller.

Of the thirty-four fourth-year students taking this course, five take the locomotive, seven the marine, and twenty-one the mill option.

Course III. *Mining, Engineering, and Metallurgy.*— The recent large development of the engineering courses of the Institute has afforded a favorable opportunity for the further specialization of the course in mining in the directions of civil, mechanical, and electrical engineering.

The mining and metallurgical professions have in the past exacted greatly varying requirements from their followers, calling upon young men to fit themselves in many branches, such as civil engineering, mechanical engineering, chemistry, and geology. This variety has been called for, partly by the primitive conditions of the profession in this country, necessitating, for a given place, a wide range in attainment; partly also from the fact that our students have sought for variety in order that they might have a wider range of choice. The time for this more general mining course has now gone by. The demand at present plainly indicates that it is better for a young man to fit himself more thoroughly in fewer directions, deciding at the outset what line of work he wishes to pursue, and devoting himself to that.

The Faculty have been guided by the above considerations in planning the new mining schedules, and have laid out the mining and metallurgical courses under four different headings, two leading to mining and two to metallurgy.

The first course prepares a student to begin his work in line for promotion in any mining industry,—as a miner, a foreman, assistant manager, or manager of a mine. It fits him in geology, mining, milling, and in mechanical engineering adapted to mining.

The second course prepares a student to take position

in line for promotion in a surveyor's office in a mining district, as assistant surveyor, as surveyor of mines, as consulting mining engineer, as mine superintendent. It fits him in geology, mining, milling, and in civil engineering adapted to mining, construction of railroads, electric railroads, canals, roads, buildings, bridges, etc.

The third course fits a student to take position in line for promotion in a smelting works as a hand, as foreman, assistant superintendent, or superintendent, or he may enter the works through the chemical laboratory. It fits him in analytical chemistry, metallurgy, mathematics, and in mechanical engineering adapted to metallurgy.

The fourth course fits a student to take position in line for promotion in a smelting works as assistant chemist, as chemist, as furnace manager, as superintendent. It fits him in analytical and theoretical chemistry, in metallurgy, in electrometallurgy.

Course IV. *Architecture.* — In the Architectural department the strengthening of the two-years' partial course has worked very satisfactorily, and has already had the effect of bringing to the Institute an abler class of young men, as is shown by the improved work of this year. It has attracted draughtsmen who have been willing to leave good situations, confident that this course will make their future success more certain. These older and stronger men are exerting an excellent influence upon the department; and it is gratifying to report that, while only ten students entered last year, intending to pursue the regular course, this year there are nineteen.

Feeling that the four months' vacation made too long a break from regular work, Prof. Chandler, at the close of the last school year, requested such students as were not engaged in architects' offices to do a certain amount of specified work during the summer. This request was responded to by the students with great cordiality, and excellent results have been shown.

To the regular studies will be added this year a course in acoustics. Iron and steel construction is also to be made an important course. Beginning with the nature of materials, the student is to apply the theory of his applied mechanics to practical construction, in designing roof trusses, floors, columns, etc. The library has been largely added to, and its usefulness greatly increased by more detailed indexing, and by better facilities for reading. The department has been much benefited indirectly by the Rotch scholarship. The trustees of this fund have loaned to us certain of the envois, which are hung on the walls of drawing rooms. These beautiful drawings of historical architecture, made by finished draughtsmen, serve as a further stimulus for our young men. The Architectural department will derive great advantage, beginning with the second term of the current year, from the removal of the Civil Engineering department to the Trinity Place building. The large drawing room now occupied by the second and third year students of the latter department will, after January, be assigned to the use of the architectural students.

Course V. *Chemistry.* — The present crowded condition of the organic laboratory may call for its enlargement in the near future. The addition of a special room for organic combustions would relieve the pressure now existing here.

The demand made upon the Institute for chemists of industrial works — in the lines of dyeing, metallurgy, fertilizers, etc. — is greater than we can supply.

The analysis of the waters of Massachusetts for the State Board of Health still continues. During the past year 1,700 samples have been analyzed, making in all, to Dec. 1, 1889, 5,400 complete sanitary examinations of the natural waters of the State. This important work, involving much original research into the sanitary aspects of the water supply of cities, has made the department of Sanitary

Chemistry additionally attractive to students of Course V., four of whom will do their thesis work in this department during the current year.

A course of laboratory instruction in textile coloring has been put in operation. This course has been taken by ten students during the past year. It will be still further perfected during the present year.

The laboratory practice in the preparation of chemicals has been so far extended in the industrial laboratory that a large proportion of the pure chemicals required in the various laboratories is now produced by the students.

Course VI. *Electrical Engineering.* **VIII.** *Physics.* — During the past year there has been a considerable increase in the number of students in the departments of Physics and Electrical Engineering, which has called for a correspondingly increased expenditure of time and labor in their instruction. Notwithstanding this fact, it is thought that the various courses have been more efficient than they were before. Several of the special courses of lectures or laboratory instruction have been extended or otherwise strengthened, and the average in excellence and in amount of work done by the more advanced students has materially improved. Several papers, embracing the results of original investigation, have been published, or are nearly ready for publication.

In consequence of the growth of the department, as well as the development of physical science in general, a large increase of apparatus for instruction and research has been necessary. This has been abundantly supplied. The new dynamo room, to which reference was made in my report for last year, with its independent engine, together with the dynamos and accessories given us by the Edison Company and the Thomson-Houston Electric Company, has made it possible to give far more efficient instruction than before regarding direct-current methods, while the 500-light Thomson-Houston alternating-current dynamo, pur-

chased by the Institute, has proved invaluable in the study of various problems arising in connection with the newer modes of the distribution of electricity.

The temporary loan of several electro-motors of large capacity by the Thomson-Houston Electric Company has further allowed us to introduce additional instruction in certain new and important methods of testing dynamos and motors. It is also a satisfaction that it has proved possible, without serious difficulty or expense, to remedy the trouble formerly experienced from the jarring of the floors and walls of the building caused by the machinery in the dynamo room. The building of a foundation wall for the shafting has largely reduced the vibration; and the addition of a few piers upon which to place the heavier dynamos will probably do away with it altogether.

It should further be remarked, in this connection, that the use of electricity in lighting the new engineering building will offer to our students an opportunity to study the working of a larger direct-current dynamo than any which we at present possess, since for this purpose a 500-light United States Company's dynamo is to be provided.

During the past year two entirely new physical courses have been instituted in connection with the department of mining. Both of these are unique in their character, and should prove of much value. The subject of heat measurements of various kinds, including the measurement of high temperatures, the determination of the calorific value of fuels, and similar important topics, is one of large practical importance, regarding which very little information is now accessible to the student. And this is true, to an even greater degree, of the applications of electro-metallurgy to chemical analysis, the reduction of ores and allied problems, in which even the methods are often still to be devised. Several years must necessarily elapse before these courses are fully developed.

Course VII. *Biology.* — The number of students in biology (22) is larger than ever before. More students, also, from other departments (26) are under instruction, chiefly in general and sanitary biology. Of the 22 students who make biology their specialty, 9 are regulars and 13 specials. Of the regulars, 4 intend to become physicians, and 4 teachers or professional biologists. Of the special students, 3 are college graduates fitting themselves here for particular lines of work, 6 are about to become regular students of biology, 2 are teachers preparing themselves for higher positions, and 2 intend soon to enter upon teaching or the medical profession.

By special arrangement with the State Board of Health, the biological work of the Lawrence Experiment Station has, for the past year, been carried on in the biological laboratory under the direction of Prof. Sedgwick. His chief assistant in this work has been Mr. Edwin O. Jordan, a graduate of this department of the Institute in the Class of 1888. The results of the year include interesting contributions to sanitary biology, and are soon to be published in a special report of the State Board of Health.

Dr. E. G. Gardiner, instructor in biology, a graduate of the Institute in the Class of 1882, who has had the more immediate charge of the classes in Zoölogy, Anatomy, and Embryology, acted as assistant during the summer, in the Marine Biological Laboratory at Wood's Holl, where he conducted investigations upon *Amarœcium,* one of the compound ascidians.

Mr. Alexander L. Kean, until very recently a special student in this department, has so far completed his studies of the Bermuda lily disease, begun and carried out during his connection with the laboratory, that an important paper from his pen will appear upon that subject in the January number of the *Botanical Gazette.*

The demand which has arisen for instruction and expert aid in sanitary biology has necessitated increased facilities

until it is believed that no college or science school in the land offers larger opportunities for work and investigation in this direction than does the Institute. The library, especially when re-enforced by the biological portion of the William Ripley Nichols library, is certainly unsurpassed.

An important gift to the biological department has been made during the year by Mr. James Means, whose generosity has made possible the purchase of an extremely useful collection of Mediterranean animals, preserved and identified at the celebrated Stazione Zoölogica in Naples.

Course IX. *General Studies.* — The resignation of Prof. Atkinson of course involves large changes in this department; but for the present year provisional arrangements only have been made, through the appointment of Dr. Rand, already spoken of. It is probable that next year's report will have to deal with an extensive reorganization of the general studies of the school.

Course X. *Chemical Engineering.* — The course in chemical engineering, in which instruction was introduced last year, has been still further developed. The department receives frequent calls for men trained in mechanical engineering, and at the same time acquainted with applied chemistry. On this point I will repeat a few lines from my report of last year: —

There are a great number of industries which require constructions, for specific chemical operations, which can best be built, or can only be built, by engineers having a knowledge of the chemical processes involved. This class of industries is constantly increasing, both in number and in importance. Heretofore, the required constructions have, generally speaking, been designed and work upon them has been supervised and conducted, either by chemists having an inadequate knowledge of engineering principles and unfamiliar with engineering, or even building, practice; or else by engineers whose designs were certain to be either more laborious and expensive than was neces-

sary, or less efficient than was desirable, because they did not thoroughly understand the objects in view, having no familiarity, or little familiarity, with the chemical conditions under which the processes of manufacture concerned must be carried on. It was to meet this demand for engineers having a good knowledge of general and applied chemistry, that the course in chemical engineering was established.

The instruction thus far given, while following mainly in the line of mechanical engineering, has included an extended study of industrial chemistry, with laboratory practice, in the third year.

The arrangement of the course of study has now been completed. A considerable portion of the time in the fourth year will be devoted to mechanical engineering and general applied chemistry, but a series of options has been introduced, designed to specialize the work more highly, either in the line of the textile industries, of furnace construction and regulation, or of the manufacture of organic products. A special course of lectures is to be given by Prof. Peabody, devoted to the discussion of chemical machinery from the engineering point of view. It is believed that this course will prove of the greatest value to the students in chemical engineering. It will deal with problems, some of which have not hitherto been dealt with in a systematic way for purposes of instruction, such as pumping machinery for gases and liquids, refrigerating machinery, filter presses and other forms of presses, methods for evaporation *in vacuo*, and other special problems with which the chemical engineer has to deal.

Course XI. *Sanitary Engineering.* — The establishment last year of Course X., in addition to the traditional nine courses at the Institute, has been followed this year by the inauguration of still another course, in sanitary engineering, to be known as Course XI. Six students of the present second year's class have enrolled themselves in this course.

The nature of the course is, perhaps, sufficiently indicated by its title, yet a somewhat detailed account of its character and of the causes which led to its adoption may be of interest.

The rapid advances in sanitary science and the increasing necessity for co-operation between the engineer, the chemist, and the biologist, in dealing with questions affecting the public health, appeared to render desirable a course which should afford students an opportunity to master so much of the subjects of chemistry and biology as should fit them properly to interpret the results of sanitary chemistry and sanitary biology, and to appreciate their bearing upon engineering problems.

The course of study is essentially one in civil engineering. It is not the object to make chemists or biologists; and the courses in chemistry and biology, though continuous, are very moderate in amount. But by giving the student a firmer grasp of these subjects, by teaching him to think in chemical or biological language, it is hoped to enable him to deal somewhat more intelligently with the questions which come within the province of the sanitary engineer.

The course differs from the regular course in civil engineering in the following particulars: —

(*a.*) There is a reduction in the time devoted to railroads and bridges, and an entire omission of the mechanical engineering subjects of mechanism, machinery, and motors, and of the subjects of astronomy, metallurgy of iron, and historical geology.

(*b.*) The time thus gained is devoted principally to courses in chemistry and biology. In the fourth year, a course of instruction is also given in heating and ventilation.

(*c.*) The entire instruction in sanitary and hydraulic engineering, now given in the course in civil engineering, a portion of which is there optional with other studies, is required in the course in sanitary engineering.

In the second year, brief courses in organic chemistry and chemical analysis are introduced; in the third year, chemical analysis, water analysis, and biology; and in the fourth year, advanced analysis, chemistry, and biology of natural waters, and sanitary biology and bacteriology, take the place of certain purely engineering subjects.

LOWELL SCHOOL OF INDUSTRIAL DESIGN.

The Lowell School of Industrial Design has since my last report had a thoroughly successful year. The exhibition of the work of the pupils, made at the time of the annual graduating exercises of the School of Industrial Science, was highly creditable, a distinct improvement being manifested even over the admirable exhibit of 1888. Much of the best work of the year, however, could not be shown, owing to the fact that numerous designs for wall papers and for prints had been sold by the pupils to manufacturers.

Of the ten graduates of May, seven have already obtained situations in different mills. The session of 1889–90 began with fifty-three pupils, the maximum number allowed. Of these thirty-three were former pupils. Since the school began in October, six of the pupils have left the school to take situations in manufacturing establishments. According to our usage, the certificates of these students will be delivered to them in connection with the next graduating exercises, their work in the mills being accepted in substitution for the remaining work of their school course. A new feature of the work of the present year is the introduction of china painting, for which provision has been made by taking in a portion of the room formerly occupied by the drawing classes of the School of Mechanic Arts.

By the kindness of the owners of various mills in Lowell, Lawrence, and elsewhere, pupils have had opportunities to visit the weaving departments of those mills.

At the close of the last school year, Miss Delphina Weston, after a valued service of four years, resigned her position as assistant in the Lowell School, and Mrs. Minnie Gray was appointed to her place. Mr. Albert Bryant continues in charge of the weaving department of the school.

OBITUARY.

The Corporation has lost by death four valued members during the past year. Mr. James L. Little was one of the charter members of the Corporation, and even before that had been active among the projectors of the Institute of Technology. For many years he was most zealous and attentive to his duties as a Trustee. His courage and his faith in the future of the school were no small part of the force which kept it alive in the days of darkness and doubt which now seem so far back in the past. Of late years increasing infirmities have kept him from active participation in our affairs.

Mr. Edward S. Philbrick became a member of the Corporation in 1866, and from that time forward was among the most active of its supporters. He gave of his time and personal attention as much, perhaps, as any member of the Corporation, holding himself always subject to call whenever his professional assistance or his practical judgment was in request. He was chairman of the Building Committee having in charge the erection of the new building of 1883. At the time of his decease he was Chairman of the Visiting Committee of the Corporation on the department of Civil Engineering.

Mr. Charles L. Flint was elected to the Corporation in 1865, and served as a zealous and scrupulously attentive member during the remainder of his life. He was one of the Committee on the School of Industrial Science until that Committee was discontinued on the reorganization of the Corporation, when he became Chairman of the Visiting Committee on the department of Modern Languages. The

exceptional qualifications for public service which Mr. Flint exhibited during so many years as Secretary of the State Board of Agriculture, made him a valuable member of the Corporation of the Institute.

Were I to attempt an eulogy of Mr. Stanton Blake, the tender recollections of forty years of personal friendship would so mingle with the sense of the official loss sustained through his untimely death, as to make it difficult for me to choose my words on this occasion. But the qualities of head and of heart which united to make Mr. Blake the friend and staunch supporter of every good cause, are all too well known to this Board and too fresh in our remembrance to require panegyric here.

TREASURER'S REPORT.

STATEMENT OF THE TREASURER.

The Treasurer submits the annual statement of the financial affairs of the Institute for the year ending Sept. 30, 1889.

During the year the only change of importance in the investments has been the sale of $25,000 Gulf, Colorado and Santa Fé first mortgage 7s, and the purchase of the same amount of $25,000 Kansas City Belt Line 6s bonds for the account of the Wm. Barton Rogers Memorial Fund.

An estimated value of one-tenth undivided interest in estate 1004 Walnut Street, Philadelphia, bequeathed to the Institute by Robert E. Rogers, of Philadelphia, has been entered on the books at $2,500.00.

The income from general investments has been divided at the rate of $4\frac{696}{1000}$ per cent among the funds to which it belongs, and the balance of ten cents remaining after division carried to Profit and Loss.

Gifts and bequests have been received from —

State of Massachusetts	$100,000 00
Subscription of 1887	38,500 00
Estate of Mrs. Susan H. Swett to found Susan H. Swett Scholarship Fund	10,000 00
Mrs. Mary E. Atkins to found Farnsworth Scholarship Fund	5,000 00
Estate of Stanton Blake	5,000 00
" " Sidney Bartlett	10,000 00
Mrs. Wm. B. Rogers for periodicals	100 00
James Means for Biological Laboratory	200 00
Estate of William Perry, of Brockton, and used to defray current expenses	885 22
Alumni of Institute towards Wm. B. Rogers Scholarship Fund	1,000 00

Statement of Lewis William Tappan, Jr., Treasurer

RECEIPTS.

Augustus Lowell, Trustee		$2,500 00
" " "		2,200 00

APPLIED TO CURRENT EXPENSES.

From Income of Funds for Salaries.	A	$4,113 70	
" " " " " Scholarships.	A	3,376 80	
" " " " " General Purposes.	A	5,175 95	
" Income Joy Fund, specially invested		200 00	
" " Wm. Barton Rogers Memorial Fund.	B	12,511 25	
" previous income Richard Perkins Scholarship Fund		19 13	
" James Henry Mirrlees Scholarship Fund		1 71	
" Students' Fees		158,026 50	
" Laboratory Breakage and Supplies		4,012 93	
" Sale of Printed Lecture Notes		1,799 63	
" State Agricultural Fund		5,504 42	
" Boston University		1,150 00	
" Rents. **Table I.**		6,427 50	
" Gifts		300 00	
" Estate of Wm. Perry of Brockton		885 22	
			$203,504 74

OTHER RECEIPTS.

From State of Massachusetts		$100,000 00	
" Subscription of 1887		38,500 00	
" Estate of Mrs. Susan H. Swett		10,000 00	
" Mrs. Mary E. Atkins		5,000 00	
" Estate of Sidney Bartlett		10,000 00	
" " " Stanton Blake		5,000 00	
" " " Robert E. Rogers		2,500 00	
" Alumni W. B. Rogers Scholarship		1,000 00	
" Interest on " "		204 26	
" Income James Savage Scholarship Fund, not used		99 88	
" Students' Notes Receivable	$1,245 00		
" loss by death and charged off	200 00		
		1,445 00	
" Sale of Gulf, Colorado and Santa Fé R. R. Bonds,		27,761 75	
" Burlington and Missouri R. R. Bonds drawn		3,000 00	
" Students' Deposit		50 00	
" Augustus Lowell, Trustee, L. S. D.		1,000 00	
" Shawmut Bank	$445 93		
" last Cash Balance	8,412 07		
		8,858 00	
			214,418 89

SUNDRIES.

From Income Wm. Barton Rogers M. F., credited to Advance Bonds Premiums		$1,111 86	
" Transferred from Advance Bonds Premiums. Contra		272 00	
" Advance for Accrued Interest credited to Advance Bonds Premiums		1 33	
" Balance of Profit and Loss used to reduce Gymnasium Account		33 19	
			1,418 38
			$419,342 01

of the Massachusetts Institute of Technology.

DISBURSEMENTS.

Lowell Courses		$2,500 00
Charles Kastner's Salary		2,200 00

EXPENSES.

Rents	$180 00	
Repairs	3,506 22	
Laboratory Supplies. **Table II.**	25,047 21	
Salaries. **Table III.**	137,472 83	
Printing and Advertising	2,068 28	
" Lecture Notes	1,657 62	
" Catalogue, 1888–89	1,179 97	
General Expenses. **Table V.**	8,217 19	
Fuel, Water, and Gas. **Table IV.**	8,363 99	
Interest. **Table VI.**	6,584 95	
Scholarships	3,625 00	
Society of Arts	175 06	
Physical Laboratory Improvement	2,827 86	
New Boiler	995 81	
Profit and Loss	1,569 56	
		$203,471 55
Balance		33 19
See below. Contra.		$203,504 74

PAYMENTS.

Lowell School of Design	$926 11	
Notes Payable	101,000 00	
Massachusetts Charitable Mechanic Association	4,000 00	
		105,926 11

PURCHASES.

Everett Mills, 17½ Shares, 50%	$875 00	
Kansas City Belt Line Bonds	28,500 00	
Policy Massachusetts Hospital Life Insurance Co.	10,000 00	
Burlington & Missouri R. R. Nebraska Bond	1,063 75	
		40,438 75

SUNDRIES.

$\frac{1}{10}$ Estate 1004 Walnut Street, Philadelphia	$2,500 00	
Building on Trinity Place	39,327 53	
Taxes on Trinity Place Land	638 39	
Joy Scholarship Fund	143 53	
Richard Perkins Scholarship Fund	19 13	
James Henry Mirrlees Scholarship Fund	1 71	
		42,630 29
Wm. Barton Rogers M. F. Advances Bonds Premium. Contra	$272 00	
		272 00
Cash Balance		26,570 12
		$419,342 01

A.

INCOME FROM GENERAL INVESTMENTS, AND APPLICATION THEREOF.

Applied to Salaries		$4,113 70	
" " Scholarships		3,376 80	
" " General purposes		5,175 85	
" " Profit and Loss		10	
" " Increase of Funds		304 14	
		$12,970 59	
From Dividends, Old Boston Bank			$302 50
" State Tax returned, Old Boston Bank			86 09
" Railroad Bonds			4,546 17
" Essex Co. Dividends			216 00
" Chicago, Burlington and Quincy Railroad Dividends			560 00
" Cocheco Manufacturing Company Dividends,			240 00
" Hamilton Woollen Company Dividends			300 00
" Everett Mills Dividends			70 00
" Joy Scholarship Fund			143 53
" Rent, 1004 Walnut Street, Philadelphia			134 68
" Wm. B. Rogers Memorial Fund over-invested, $7,284.50, @ 5%			364 22
" Interest, Students' Notes Receivable			162 63
" " Shawmut Bank			1,491 44
" " on Uninvested Funds, @ $4\frac{696}{1000}$, being rate of earnings of funds invested			4,353 33
			$12,970 59

B.

INCOME FROM WILLIAM BARTON ROGERS MEMORIAL FUND, AND APPLICATION THEREOF.

Paid Massachusetts Institute of Technology 5%		From Railroad Bonds	$13,107 33
on Amount of Fund ($250,225)	$12,511 25	Chicago, Burlington & Quincy R. R. Dividends,	
Paid Massachusetts Institute of Technology 5%		220 shares	880 00
on Amount Borrowed (over-invested)	364 22		
Credited to Advance to Bonds Premiums	1,111 86		
	$13,987 33		$13,987 33

TABLE I. — Rents Received.

Huntington Hall for Lowell Lectures	$2,500 00	
Lowell School of Design	1,000 00	
Chauncy Hall School for Gymnasium	300 00	
State Board of Health for use of Laboratories	2,325 00	
Use of Lecture Rooms	52 50	
Green-house on Trinity Place	250 00	
		$6,427 50

TABLE II. — Department Supplies

Chemical Department	$7,117 95	
Mining "	1,321 33	
Physical "	4,779 80	
Mechanical Engineering Department	1,147 72	
Applied Mechanics "	836 42	
Mechanic Arts "	1,413 98	
Civil Engineering "	1,515 28	
Biological "	1,661 98	
Geological "	105 20	
Architectural "	2,655 77	
Drawing "	112 96	
English "	1,413 67	
Periodicals	965 15	
		$25,047 21

TABLE III. — Salaries.

Paid for Instruction	$113,019 49	
" Administration	12,566 49	
" Labor	11,886 85	
		$137,472 83

TABLE IV. — Fuel, Water, and Gas.

Paid for Fuel	$5,625 34	
" Water	910 70	
" Gas	1,827 95	
		$8,363 99

TABLE V. — General Expense.

Insurance	$1,516 00	
Postage and Stationery	1,022 30	
Furniture	1,251 60	
Diplomas, Commissions, and Expense of Drills	304 90	
Entrance Examinations	644 50	
Paris Exposition	191 07	
Subscription to Technology Quarterly	150 00	
Gift to Technology Quarterly	500 00	
Electric Lighting	152 84	
Expressage	267 37	
Ice (Boston Ice Co.)	166 67	
Washing	244 65	
Damper Regulator (Locke Bros.)	185 00	
Covering Steam Pipes (Trainer & Co.)	235 48	
Oil for Engine	81 98	
Examining Elevator (Whittier Machine Co.)	24 00	
Paving Sidewalk and pointing around Chimney (R. S. Dewing)	40 35	
Carting away Rubbish, etc. (J. Gormley)	33 88	
Prints for Drawings (D. A. Gregg)	58 00	
Rent Union Safe Deposit Vaults	50 00	
Towels, etc. (C. F. Hovey & Co.)	78 23	
Paint, Varnish, etc. (J. A. & W. Bird & Co.)	332 18	
Pails, Brushes, etc.	163 14	
Reducing Valve (Mason Regulator Co.)	42 75	
Window Glass (Page, Harding & Co.)	74 70	
Office Supplies (Cyclostyle Paper, Ink, etc.)	140 57	
Printing Treasurer's Report	20 00	
Ventilation (W. H. Blake and others)	46 45	
Making Keys (T. Margeson)	21 50	
Check Books (J. Ottmann)	47 00	
Sundries	130 08	
		$8,217 19

TABLE VI. — Interest Paid.

Moses Williams, Trustee, on Mortgage	$620 14	
Alumni Association	58 33	
Shawmut Bank	553 15	
Augustus Lowell, Trustee	1,000 00	
On $92,702.92 Uninvested Funds	4,353 33	
		$6,584 95

TRIAL

INVESTMENTS.

BONDS.

INVESTMENT OF WM. BARTON ROGERS MEMORIAL FUND.

Cin., Ind., St. Louis, and Chicago R. R. 6s		$4,000 00	
Omaha & Southwestern R. R. 8s		7,000 00	
Mo. Valley, Blair R'y & Bridge R. R. 6s		20,000 00	
Saginaw & Western R. R. 6s		50,000 00	
Kansas City, Clinton & Springfield R. R. 5s		16,000 00	
Republican Valley R. R. 6s		5,400 00	
Kansas City, Emporia & Southern R. R. 7s		7,000 00	
Kansas City, Memphis & Birmingham R. R. 5s		1,905 00	
Grand Rapids, Newaygo & L. Shore R. R. 8s		34,000 00	
Burlington & Mo. River R. R. 4s		25,787 50	
Kansas City, Lawrence & Southern R. R. 6s		6,000 00	
Cowley, Sumner & Ft. Smith R. R. 7s		2,000 00	
Ottawa, Oswego & Fox River R. R. 8s		2,000 00	
Quincy & Warsaw R. R. 8s		4,000 00	
Lincoln & Northwestern R. R. 7s		1,000 00	
Atchison & Nebraska R. R. 7s		1,000 00	
Florence, Eldorado & Wt. Valley R. R. 7s		1,000 00	
Kansas City Belt Line 6s		25,000 00	
		$213,092 50	
220 shares Chi., Bur. & Quincy R. R.		22,000 00	
Advances to Premiums on Bonds	$18,821 39		
" " " Stock	2,483 75		
		21,305 14	
			$256,397 64

INVESTMENT OF JOY SCHOLARSHIP FUND.

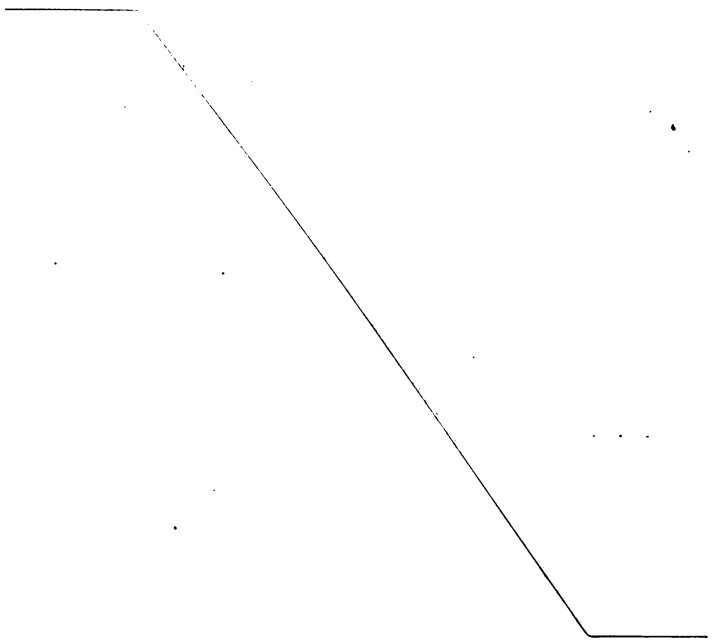
Mass. Hospital Life Insurance Co.	$5,000 00	
Deposits in Savings Bank	2,513 50	
		7,513 50

INVESTMENT OF MRS. SUSAN H. SWETT SCHOLARSHIP FUND.

Mass. Hospital Life Insurance Co.	10,000 00
Amount carried forward	$273,911 14

BALANCE.

FUNDS.



Wm. Barton Rogers Memorial Fund	$250,225 00
Joy Scholarship Fund	7,513 50
Mrs. Susan H Swett Scholarship Fund	10,000 00
Amount carried forward	$267,738 50

OTHER PROPERTIES OF THE MASS. INSTITUTE OF TECHNOLOGY AS THE SAME APPEAR ON LEDGER.

BONDS.		
Amount brought forward		$273,911 14
Quincy & Palmyra R. R. 8s	$25,000 00	
Chicago, Burlington & Quincy R. R. 4s	5,100 00	
Burl. & Mo. River R. R. Land Grant 7s	15,000 00	
Burl. & Mo. River R. R., Nebraska, 6s	19,000 00	
		64,100 00
STOCKS.		
Chicago, Burl. & Quincy R. R., 140 shares	$14,000 00	
Old Boston National Bank, 55 shares	5,510 50	
Cocheco Manufacturing Co., 12 shares	6,000 00	
Everett Mills, 35 shares	3,150 00	
Hamilton Woollen Co., 50 shares	5,000 00	
Essex Co., 27 shares	4,050 00	
		37,710 50
SUNDRIES.		
Notes Receivable	$1,500 00	
Students' Notes Receivable	5,905 00	
Lowell School of Design	127 41	
Cash	26,570 12	
		34,102 53
REAL ESTATE.		
1-10 1004 Walnut St., Philadelphia	$2,500 00	
Rogers Building	315,726 88	
New building of 1883	190,492 44	
Mechanic Arts Building	52,416 49	
Land on Garrison St.	50,840 00	
Gymnasium	3,713 36	
Land on Trinity Place	76,315 69	
Building on Trinity Place	39,327 53	
		731,332 39
Mechanic Arts Equipment		20,628 56
		$1,161,785 12

BALANCE.– (Continued.)

Amount brought forward		$267,738 50
James Hayward, for Professorship of Civil Engineering	$18,800 00	
Nathaniel Thayer, for Professorship of Physics	25,000 00	
Wm. P. Mason, for Professorship of Geology,	18,800 00	
Henry B. Rogers, for Salaries of Professors, etc.	25,000 00	
		87,600 00
Thomas Sherwin Scholarship Fund	$5,000 00	
James Savage " "	10,744 64	
James Henry Mirrlees " "	2,623 76	
Wm. Barton Rogers " "	5,553 96	
Richard Perkins " "	51,745 57	
Farnsworth " "	5,000 00	
		80,667 93
INCOME OF THE FOLLOWING FUNDS IS USED FOR GENERAL PURPOSES OF THE INSTITUTE.		
Albion K. P. Welch Fund	$5,000 00	
McGregor "	2,500 00	
Nathaniel C. Nash "	10,000 00	
Robert E. Rogers "	6,690 29	
General "	36,028 00	
Richard Perkins "	50,000 00	
		110,218 29
Estate Stanton Blake	$5,000 00	
" Sidney Bartlett	10,000 00	
		15,000 00
Subscriptions of 1887	$87,500 00	
M. I. T. Stock Account	483,164 15	
		570,664 15
Income Joy Fund		200 00
Advances to Bond Premiums		9,146 25
DEBTS.		
Note Payable	$20,000 00	
Students' Deposits	550 00	
		20,550 00
		$1,161,785 12

E. & O. E. LEWIS WM. TAPPAN, JR., *Treasurer.*

BOSTON, Dec. 2, 1889.

An examination of the accounts of the Treasurer of the Massachusetts Institute of Technology for the year ending Sept. 30, 1889, has been made, and they are found to be correctly cast, and with proper vouchers. The Ledger Balances agree with the Trial Balance. We have verified the evidences of personal property held by the Institute.

FREDERIC W. LINCOLN, } *Auditing*
PERCIVAL LOWELL, } *Committee.*

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ANNUAL REPORT

OF THE

PRESIDENT AND TREASURER

OF THE

MASSACHUSETTS

INSTITUTE OF TECHNOLOGY,

DEC. 10, 1890.

BOSTON:
ALFRED MUDGE & SON, PRINTERS,
24 FRANKLIN STREET.
1891.

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HON. WALBRIDGE A. FIELD, *Chief Justice of the Supreme Court.*
HON. JOHN W. DICKINSON, *Secretary of the Board of Education.*

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ARTHUR T. LYMAN. SAMUEL CABOT.
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Lowell School of Practical Design.

PERCIVAL LOWELL. M. DENMAN ROSS.
JOHN D. RUNKLE.

To the Corporation of the Massachusetts Institute of Technology:

Since my last annual report, one school year has ended happily, and another has opened with the fairest prospects. On the 3d of June, the degree of Bachelor of Science was conferred upon one hundred and two members of the class of 1890, and upon one member of a preceding class who had supplied certain requirements previously lacking. The degree of Master of Science was conferred upon a member of the class of 1889, after the completion of a year of additional study.

Inasmuch as Graduation Day of 1890 marked the close of the first quarter-century in the life of the Institute, it was made the occasion of a commemorative address by Augustus Lowell, Esq., of the Corporation and of the Executive Committee, in which the work of twenty-five years was reviewed, and the contributions of the school to the cause of scientific and technical education were set forth, both for the encouragement of the governors, teachers, alumni, and other friends of the Institute, and as an historical record of interest.

Of the 102 graduating members of the class of 1890, 25 graduated in civil engineering, 27 in mechanical engineering, 3 in mining engineering, 5 in architecture, 13 in chemistry, 18 in electrical engineering, 3 in biology, 2 in physics; 6 graduated from the department of general studies. All courses of the school were thus represented in the award of diplomas. The fourth-year students of the year now current comprise candidates for the degree of the Institute, in each of the nine courses named, and also,

for the first time, in chemical engineering, that course (X.) having been opened to students at the beginning of the school year 1888–89. The course in sanitary engineering (XI.) will not present candidates for a degree until the school year next following,

The new year has witnessed an increase, though not a large increase, in the number of students in the school. The total registration this year, as by the catalogue now in press, amounts to 937 against 909 last year, a gain of 28. The following table exhibits the number of students in the school each year, from the opening of the Institute to the present time:—

Year.	No. of Students.	Year.	No. of Students.
1865–66	72	1878–79	188
1866–67	137	1879–80	203
1867–68	167	1880–81	253
1868–69	172	1881–82	302
1869–70	206	1882–83	368
1870–71	224	1883–84	443
1871–72	261	1884–85	579
1872–73	348	1885–86	609
1873–74	276	1886–87	637
1874–75	248	1887–88	720
1875–76	255	1888–89	827
1876–77	215	1889–90	909
1877–78	194	1890–91	937

STUDENTS BY CLASSES.

The aggregate numberof students for 1890–91 is divided among the several classes as follows:—

Graduate student, candidate for advanced degree	1
Regular students, Fourth Year	115
" " Third Year	138
" " Second Year	154
" " First Year	250
Special students	279
Total	937

Assigning the special students to classes, according to the predominant studies pursued by them, we reach the following statement of the division of the whole body among the several years : —

Class.	Regular.	Special.	Total.
Graduate of the M. I. T., candidate for an advanced degree .	1	..	1
Fourth Year	115	32	147
Third Year	138	71	209
Second Year	154	84	238
First Year	250	92	342
	658	279	937

STATISTICS OF EXAMINATIONS.

Of the 937 students of the present year, 365 were not connected with the school in 1889–90.

Fourteen had been connected with the Institute at some previous time, and returned to resume their places in the school; 26 were admitted provisionally, without examination ; 60 were admitted on the presentation of diplomas or certificates from other institutions.

Excluding from consideration those who were admitted but have not, in fact, entered the school, 36 in number, the following was the result of the examinations held : —

Admitted clear		165
" on one condition	51	
" " two conditions	28	
" " three "	13	
" " more than three conditions	8	100
Rejected		64
		329

EXAMINATIONS AT DISTANT POINTS.

In addition to the entrance examinations held in Boston in June and September, 1890, examinations were also con-

ducted, in June, at Chicago, Cincinnati, Montreal, New York, Philadelphia, Pittsburg, Portland, Ore., San Francisco, St. Louis, St. Paul, and Washington.

RESIDENCE OF STUDENTS.

Thirty-eight States of the Union, besides the District of Columbia, are represented on our list of students. Of the total number of 937, including special students, 517 are from Massachusetts, or 55.2 per cent of the whole; 108 are from other New England States; 312 from outside New England, of whom 36 are from foreign countries.

The following table shows the number of students of each specified class from each State or foreign country: —

State.	Candidate for Advanced Degree.	Fourth Year.	Third Year.	Second Year.	First Year.	All Regular Students.	Special Students.	Total.
Arkansas	....	2	..	..	1	3	...	3
California	....	..	4	..	7	11	3	14
Colorado	....	..	..	1	1	2	2	4
Connecticut	....	4	3	6	3	16	15	31
Delaware	....	..	..	..	1	1	...	1
Dist. Columbia	....	1	..	..	3	4	3	7
Florida	....	1	..	1	1	3	...	3
Georgia	....	..	1	..	1	2	...	2
Illinois	....	6	8	7	9	30	4	34
Indiana	....	1	..	..	1	2	4	6
Iowa	....	..	..	1	2	3	6	9
Kansas	....	..	..	..	1	1	1	2
Kentucky	....	..	1	1	1	3	1	4
Louisiana	....	..	1	..	5	6	2	8
Maine	....	3	3	6	2	14	15	29
Maryland	....	..	2	..	2	4	3	7
Massachusetts	1	63	80	99	137	380	137	517
Michigan	....	3	4	1	2	10	6	16
Minnesota	....	..	1	2	4	7	5	12
Missouri	....	..	1	2	2	5	3	8
Montana	....	..	..	..	...	...	1	1
Nebraska	....	..	..	..	...	...	1	1
Nevada	....	..	..	..	1	1	...	1
N. Hampshire	....	3	2	2	5	12	11	23
New Jersey	....	1	2	4	2	9	2	11
New York	....	7	3	5	11	26	14	40
No. Carolina	....	..	1	..	...	1	...	1
Ohio	....	6	5	5	7	23	10	33
Oregon	....	1	..	..	...	1	...	1
Pennsylvania	....	2	4	4	6	16	6	22
Rhode Island	....	3	3	3	9	18	3	21
So. Carolina	....	...	...	...	2	2	...	2
Tennessee	....	1	...	...	1	2	1	3
Texas	....	...	...	...	...	...	1	1
Vermont	....	1	...	...	2	3	1	4
Virginia	....	...	2	...	3	5	...	5
Washington	....	1	1	...	...	2	...	2
West Virginia	....	...	...	2	...	2	...	2
Wisconsin	....	2	2	...	4	8	2	10
Foreign Countries.								
Arg. Republic	....	...	...	...	1	1	1	2
Brazil	....	...	...	...	...	...	2	2
Bulgaria	....	..	1	...	...	1	...	1
England	....	...	...	...	1	1	1	2
France	....	...	...	...	1	1	...	1
Hawaiian Islds	....	...	...	...	2	2	2	4
Ireland	....	1	...	...	...	1	...	1
Japan	....	...	...	1	1	2	2	4
Mexico	....	...	...	...	...	...	1	1
N. Brunswick	....	...	1	...	...	1	...	1
Nova Scotia	....	...	...	...	1	1	1	2
Peru	....	...	...	...	1	1	2	3
Porto Rico	....	1	...	...	...	1	1	2
Prov. Ontario	....	...	...	...	1	1	...	1
Prov. Quebec	....	1	...	...	2	3	1	4
Scotland	....	...	1	1	...	2	1	3
Trinidad	....	...	...	...	...	...	1	1
Turkey	....	...	1	...	...	1	..	1
Total	1	115	138	154	250	658	279	937

RESIDENCE OF MASSACHUSETTS STUDENTS.

It has been said that 55.2 per cent of our students are from Massachusetts. All the counties of the State, except the small counties of Dukes and Nantucket, send students to the Institute. One hundred and six cities and towns are reported on the lists. The first column of the following table shows the number of cities and towns in each county sending pupils to the Institute; the second column gives the aggregate number from each county. It appears that Middlesex sends us 164 pupils; Suffolk comes next, with 156; Essex third, with 60; Norfolk fourth, with 51. Last year Suffolk County led the list.

County.	No. of Towns.	No. of Students.	County.	No. of Towns.	No. of Students.
Barnstable	4	5	Hampden	4	8
Berkshire	3	4	Middlesex	32	164
Bristol	5	21	Norfolk	17	51
Essex	15	60	Plymouth	12	24
Franklin	1	1	Suffolk	3	156
Hampshire	2	4	Worcester	8	19
	30	95	Total	106	517

The following is a list of the towns, thirty-three in number, which send four or more scholars to the Institute:—

Boston 143	Fall River 8	Dedham 4
Newton 29	Lawrence 7	Gloucester 4
Cambridge . . . 21	Framingham . . . 6	Hingham 4
Brookline 18	Melrose 6	Hyde Park 4
Lynn 14	New Bedford . . . 6	Kingston 4
Lowell 13	Salem 6	Milton 4
Newburyport . . . 13	Watertown 6	Stoneham 4
Chelsea 12	Arlington 5	Wellesley 4
Waltham 11	Fitchburg 5	Weymouth 4
Malden 10	Medford 5	Winchester 4
Somerville 10	Taunton 5	Worcester 4

PROPORTION OF OLD AND OF NEW STUDENTS.

The following table exhibits, for each year since 1883, the distribution of the total number of students among two classes: first, those students whose names are found upon the Catalogue of the year preceding; and secondly, those students whose names appear as new names upon the Catalogue of the year to which the statement relates: —

Year.	(1) Total No. of Students.	(2) No. of Students in the Catalogue of the previous year who remain in the Institute.	(3) No. of New Students entering before issue of Catalogue.	(4) Of those in column (3) the following number are regular first-year Students.	(5) No. of New Students not of the regular first-year class.
1883–84	443	231	212	140	72
1884–85	579	311	268	186	82
1885–86	609	369	240	177	63
1886–87	637	379	258	190	68
1887–88	720	396	324	229	95
1888–89	827	465	362	245	117
1889–90	909	557	352	255	97
1890–91	937	572	365	234 *	131

It appears from the foregoing that the number of students remaining over has been increased by 15, while the number registered for the first time is larger by 13, making the net gain, as previously stated, 28.

AGES OF STUDENTS ON ENTRANCE.

The next table exhibits the ages of our students upon entrance. The regular students of the first-year class number 250. From these we should except 4 cases of students of unusual ages. These deductions leave 246 as the number of students whose ages have been made the subject of computation.

* In addition, 16 students are repeating the first year.

The results appear in the following table, in comparison with the corresponding results for 1889–90 : —

Period of Life.	1889–90.		1890–91.	
	Half-Year Groups.	Yearly Groups.	Half-Year Groups.	Yearly Groups.
16 to 16½ years	1	.	1	..
16½ to 17 years	9	10	10	11
17 to 17½ years	26	..	11	..
17½ to 18 years	49	75	32	43
18 to 18½ years	58	..	48	..
18½ to 19 years	43	101	53	101
19 to 19½ years	30	..	38	..
19½ to 20 years	10	40	24	62
20 to 20½ years	12	..	10	..
20½ to 21 years	10	22	9	19
21 to 22 years	7	7	10	10
	255	255	246	246

From the foregoing tables it appears that the average age of the 246 students taken for this comparison, the present year, is 225.66 months, or 18 years 8 months and 15 days. This compares with the corresponding figures relating to previous entering classes as follows : —

	Av. Age in Months.
Class of 1890	219.91
Class of 1891	221.55
Class of 1892	223.50
Class of 1893	222.40
Class of 1894	225.66

We have here the most marked increase in the age of our entering students which has taken place since these statistics were first compiled.

In this connection it may be interesting to note the ages at graduation of the class leaving us in June. The 102

members of the class were distributed among the several periods of life, as follows: —

Under 20	8	Between 22 and 23	22
Between 20 and 20½	4	" 23 and 24	10
" 20½ and 21	10	24 and over	18
" 21 and 21½	11		—
" 21½ and 22	19		102

Here, again, we note a gain, in the age of graduation, over the class leaving the Institute in 1889.

PROPORTION OF REGULAR AND OF SPECIAL STUDENTS.

The following table exhibits both the absolute number of regular and of special students, as by the Catalogue of each successive year since 1882, and the proportion existing between these two classes: —

Year.	No. of Regular Students.	No. of Special Students.	Total No. of Students.	Percentage.	
				Regular.	Special.
1882–83	219	149	368	60	40
1883–84	272	171	443	61	39
1884–85	368	211	579	64	36
1885–86	415	194	609	68	32
1886–87	442	195	637	69	31
1887–88	520	200	720	72	28
1888–89	590	237	827	71	29
1889–90	652	257	909	72	28
1890–91	658	279	937	70	30

WOMEN AS STUDENTS IN THE INSTITUTE.

The number of women pursuing courses with us last year was 33; this year it is only 23. Of this number, 2 are graduates of colleges. Of the total number, 4 are regular students of the fourth year; 4 of the third year; 1 of the second year; 3 of the first year. Eleven are

special students. Of the 9 regular students of the upper classes, 2 take Course V., chemistry; 5 Course VII., natural history; 1 Course VIII., physics; 1 Course XII., geology. Of the special students, 4 devote themselves to chemistry and physics; 5 chiefly to biology, and allied subjects; 1 to mathematics, and 1 to geology.

GRADUATES OF OTHER COLLEGES.

Forty-eight graduates of institutions conferring degrees are included in our list of students for the present year. Of these, 6 are our own graduates, of whom 1 is pursuing studies as a candidate for an advanced degree. Forty-two are graduates of other institutions pursuing courses of study with us, either as regular or as special students. Of these, 10 are graduates of Harvard University, 4 each of Brown and Yale Universities, two each of Boston University, Amherst College, and the Michigan Mining School; while one comes from each of the following institutions: Oregon State University, Oberlin College, Hobart, Swarthmore, Hamilton, Kenyon, Trinity, Robert College, Georgetown College, Smith College, Iowa State College, Alleghany College, Haverford College, Spring Hill College, Rose Polytechnic Institute, Cornell University, Denison University, and University of the City of New York.

Of the 47, not candidates for advanced degrees here, 8 are regular students of the fourth year, — 3 in civil engineering, 1 in architecture, 3 in electrical engineering, and 1 in physics; 10 are regular students in the third year, — 2 in civil engineering, 6 in electrical engineering, 1 in chemical engineering, 1 in mechanical engineering; 3 are regular students in the second year, — 1 in civil engineering, and 2 in electrical engineering; 1 is a regular student in the first year; the remaining 25 are special students.

THE COURSES OF INSTRUCTION.

The following table presents the number of students in each of the regular courses. It will be seen that this statement relates to the second, third, and fourth years, choice of courses being made only at the end of the first year: —

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Electrical Engineering.	Natural History.	Physics.	General Course.	Chemical Engineering.	Sanitary Engineering.	Geology.	Total.
4th Year Class .	24	31	4	6	13	21	4	3	1	8	..	..	115
3d " " .	29	28	5	13	6	35	5	1	5	3	7	1	138
2d " " .	26	36	9	8	8	49	2	..	7	7	..	2	154
Total . . .	79	95	18	27	27	105	11	4	13	18	7	3	407

The following table shows the figures of the total line, in the foregoing table, in comparison with the corresponding figures for the seven next preceding years: —

	Civil Engineering.	Mechanical Engineering.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Electrical Engineering.	Natural History.	Physics.	General Course.	Chemical Engineering.	Sanitary Engineering.	Geology.	Total.
1883 . .	21	33	27	5	21	18	1	..	1	..	..	..	127
1884 . .	29	54	28	9	20	30	1	1	3	..	..	..	175
1885 . .	44	74	26	10	23	41	4	1	5	..	..	..	228
1886 . .	45	75	19	13	24	52	4	2	8	..	..	..	242
1887 . .	50	89	16	18	23	61	5	6	14	..	..	..	282
1888 . .	71	100	12	21	28	74	4	5	12	11	..	..	338
1889 . .	79	99	14	30	29	91	9	5	12	14	6	..	388
1890 . .	79	95	18	27	27	105	11	4	13	18	7	3	407
Total .	418	619	160	133	195	472	39	24	68	43	13	3	2,187

The following table exhibits the number of persons who have graduated within each of the several courses, at each succeeding year since the first diplomas were conferred: —

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering.	Architecture.	Chemistry.	Metallurgy.	Electrical Engineering.	Natural History.	Physics.	General Course.	Total.
1868	6	1	6	..	..	..	..	..	..	1	14
1869	2	2	..	..	1	..	..	..	..	..	5
1870	4	2	2	..	1	..	..	..	..	1	10
1871	8	2	5	..	2	..	..	..	..	..	17
1872	3	1	5	..	3	..	..	..	..	..	12
1873	12	2	3	1	7	..	..	..	..	1	26
1874	10	4	1	1	..	..	..	..	..	2	18
1875	10	6	6	1	1	..	..	..	1	2	27
1876	12	9	7	..	5	1	..	2	3	4	43
1877	12	6	8	4	2	..	..	..	..	..	32
1878	8	2	2	3	3	..	..	..	..	1	19
1879	6	8	3	1	3	..	..	1	1	..	23
1880	3	..	3	..	1	..	..	..	..	1	8
1881	3	5	6	3	8	..	..	1	..	2	28
1882	2	5	5	3	6	..	..	1	1	1	24
1883*	3	7	5	1	3	..	..	..	..	..	19
1884	5	6	13	..	12	..	..	..	..	..	36
1885	4	6	8	2	4	..	2	..	..	1	27
1886	9	23	7	1	7	..	10	1	..	1	59
1887	10	17	8	1	9	..	8	1	1	3	58
1888	11	25	4	5	10	..	17	3	1	1	77
1889	15	23	5	3	8	..	17	1	1	2	75
1890	25	27	3	5	13	...	18	3	2	6	102
Total,	183	189	115	35	109	1	72	14	11	30	759
Deduct names counted twice											2
Net total											757

Our special students, of course, cannot be classified systematically; but the following table exhibits the number of such students pursuing each particular branch of study: —

* The degree of the Institute was this year conferred upon a member of the class of 1883, in the department of mining engineering.

NUMBER OF SPECIAL STUDENTS ATTENDING EXERCISES IN THE FOLLOWING DEPARTMENTS OF STUDY OR PRACTICE.

Acoustics	11	Literature	33
Anthropology	4	Mathematics	138
Applied Mechanics	54	Mechanism	31
Architecture	84	Mechanical Engineering	26
Astronomy	8	Metallurgy	16
Biology	10	Military Drill	19
Blowpipe Analysis	1	Mining	5
Chemistry	73	Organic Chemistry	12
Civil Engineering	23	Physics	108
Climatology	1	Physical Laboratory	4
Drawing	51	Political Economy	34
Descriptive Geometry	53	Political Science	2
Economics	4	Railroad Management	1
Electricity	18	Sanitary Chemistry	1
English	26	Sanitary Engineering	4
French	47	Spanish	2
Geology, etc.	33	Shop-work	77
German	93	Surveying	11
Heating and Ventilation	11	Textile Coloring	6
History	6	Theoretical Chemistry	2
Industrial Chemistry	11	Zoölogy	4

Total number of entries, by special students	1,158
Total number of special students	279
Average number of entries	4.1

It may be of interest to note the number of students, either regular or special, pursuing certain leading branches of study, in each of the four years, which are as follows: —

Studies.	First Year.	Second Year.	Third Year.	Fourth Year.	Total.
Mathematics	320	211	158	38	727
Chemistry	308	37	29	29	403
English	270	182	133	3	588
French	273	15	7	11	306
Physics	..	209	189	48	446
German	57	179	155	10	401
Shop-work	..	143	54	48	245

CHANGES IN BUILDINGS AND ROOMS.

The erection of the Engineering Building properly belongs to the history of 1889, although the delay in putting up the great engine actually brought that work by a few weeks within the present year. Naturally enough, there is as yet little to be added to the story of the material development of the Institute. After such an effort as was involved in the erection of the building of 1889, a school as poor as ours may well look forward to resting for a little while. What has since been done is mainly in the nature of changes in the old buildings consequent upon the departure of the civil and mechanical engineers to their new and grander abode.

In the Rogers Building, Prof. Richards has annexed to his domain all parts of the basement formerly occupied by Prof. Lanza. These acquisitions nearly double the space devoted to mining and metallurgy, allowing not only a considerable extension of the assaying department, but also the equipment of an ample and safe blowpipe-room and the establishment of a small but pleasant library and reading-room. It is not merely in the way of an increase of space that the assaying department has profited by these structural changes. The ventilation of both the assaying-room and the furnace-room has been vastly improved by throwing down the old partition walls. Indeed, the change in this respect amounts to a revolution. If the teachers and students of mining and metallurgy are not happy now, it will be useless to try to please them. Prof. Richards retains the two rooms on the third floor hitherto occupied by him, the one as a lecture-room, the other as a model-room and museum. Another change, not less welcome to others than to the miners, has been the removal of the eighty horse-power Porter-Allen engine, which, for seven years, has kept pounding away in the basement,

shaking the whole building and greatly disturbing the occupants of the first floor, at times rendering the Society of Arts room almost unfit for lectures. Prof. Richards now has his own separate engine, of fifteen horse-power, while the power required for ventilation and other purposes in the Clarendon Street Building is furnished by another engine, of equal power, situated in that building itself.

Another change, which will, it is hoped, bring both pleasure and advantage to the students of the Institute, has been wrought on the fourth floor of Rogers, by which the whole front of that story has been converted into a large, light reading-room for students in English, history, and political science. For this purpose, three rooms, viz., the old and most unsafe blowpipe-room, Prof. Schwamb's dark and gloomy model-room, and the mathematical recitation-room on the southeast corner of the building, were thrown into one ; book-cases and reading-desks were brought up from below or newly constructed ; the lighting and ventilating of the room were improved as far as possiple ; and the virtue of paint was tried to its utmost, with a very agreeable result. The graduates of the past few years, who in their time were obliged to use the small, ill-ventilated " English " reading-room in the third story, cannot fail to rejoice at learning under how much pleasanter conditions their successors in the school now read the reviews, look up the professors' references, or write out their notes. Prof. Dewey has his own office in immediate connection with the new reading-room ; the other teachers in this department keep their desks in rooms 31 and 33, on the floor below, using these at times for small classes.

The first-year mechanical drawing classes, under Prof. Faunce, so long cooped up in the "lantern" story, now occupy the large room (No. 43) on the Newbury Street side of the fourth floor. This room has desks for 199 students working at a time, while the lockers and drawers provided give accommodation for 102 more. Here, also,

are found chairs and reading-tables for thirty to fifty students of the first year, in the intervals between recitations and lectures. The room left vacant by this better provision for mechanical drawing has been taken up by the classes in freehand drawing, and has been liberally provided with special apparatus and appliances.

On the main floor, the lecture-room (No. 15) so long known as the Society of Arts room has been invaded by a much-needed extension of the Secretary's office, the remainder of the room being turned into a students' reading-room, with a small lobby for the Librarian and his assistant. The rising floor and chairs of room 15 have been carried across the hall-way into room 11, which has been fitted up in all respects like the old Society of Arts room, with the added advantage of greatly improved ventilation, as all who attend the meetings of that society will be glad to learn.

I cannot leave the Rogers Building, even in this brief survey, without alluding to the wonderful change which two coats of paint and some carpenters' and glaziers' work have wrought in the aspect of the main hall and the grand stairways. It was only when the building was seen in its new dress that any one of us came to realize how greatly it had, for twenty years, been disfigured by stained and battered walls. It is much to be hoped that the students in their goings out and comings in will respect what has been done.

In the Clarendon Street Building there has been but little change. In speaking of the chemical department, further on in this report, I shall allude to the occupation of certain rooms on the third floor of this building for the first time, for the purposes of that department. On the second floor, the architectural students have taken possession of the large drawing-room left vacant by the departure of the civil engineers; a door has been cut through from the architectural library; and this department, with

more than one hundred students, now enjoys a beautiful and commodious suite of rooms, in every way adapted to its always advancing work.

LIBRARIES.

The work of cataloguing the important departmental libraries as well as the small general library of the Institute, noted in my last report, has gone on as rapidly as Mr. Andrews' duties would permit. Mr. Andrews gave up his summer vacation to this work. The number of cards added to the catalogue during the year has been 5,161, making a total of 11,282 now written, covering 12,061 volumes and 2,636 pamphlets.

The following departmental libraries are now completely catalogued: Mining, Chemistry, Biology, Political Science, English. In regard to these libraries, the statements as to the number of volumes are exact; in respect to the remaining libraries, such statements must necessarily be approximate only.

The following is the Librarian's statement and estimate of date Sept. 30, 1890: —

Library.	No. of Volumes.
General	1,475*
Engineering	2,100*
Mining	897
Architectural	750*
Chemical	4,231
Biological	939
Political Science	3,432
Physical	2,500*
English	671
Geological	1,000*
Total	17,990

It is impossible to state or even closely to estimate the number of pamphlets in the several libraries of the Institute; but they certainly exceed eight thousand.

* Approximately.

The accessions to the libraries of the school, considered as a whole, during the year, by gift or by purchase, have been 2,455. Of these, 42 replace old editions or books bound with others, leaving 2,413 as the number of net accessions. Of these, 1,867 are bound volumes, and 546 pamphlets. Their cost and their distribution among the several libraries appear in the following table: —

Library.	Volumes.	Pamphlets.	Total Cost.
General	115	160	$78 71
Engineering	233	47	481 12
Mining	136	7	81 20
Architectural	61	1	229 32
Chemical	476	166	490 13
Biological	89	17	99 60
Political Science	463	87	462 23
Physical	99	42	196 94
English	173	2	130 58
Geological	22	17	. . .
Totals	1,867	546	$2,249 83

Neither the subscriptions to periodicals nor the expense of binding is included in the foregoing table. The number of periodicals at present subscribed for is 196. There are received by gift or through exchange, 101; making the total number of periodicals on our files, 297. Of these, 36 are received in duplicate for the necessary purposes of different departments, making the number of periodicals actually arriving, 333.

The Institute has received a number of gifts of single books, during the year, and in addition, the following more considerable gifts: —

From the late Prof. Atkinson, 62 volumes, mostly on Political Economy.

From Hon. David P. Klemptner, a set of the reports of the Massachusetts State Board of Health.

From Messrs. Longmans, Green & Co., 11 volumes of their publications.

From the Class of 1890, architectural department, a copy of l'Art Arabe, by Prisse d'Avennes.

THE CORPS OF INSTRUCTORS.

The Catalogue of 1890–91 shows the number of instructors of all grades to be 95, inclusive of those concerned with the Mechanic Arts, but exclusive of those who are announced as lecturers for the year only. The addition of these would raise the total to 109, made up as follows: —

Professors	10
Associate Professors	14
Assistant Professors	7
Instructors	38
Assistants	26
Lecturers for the year	14
	109

	Civil Engineering.	Mechanical Eng. and App. Mechanics.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Physics and Elect. Engineering.	Biology, Zoölogy, etc.	Mineralogy, Geology, and Geography.	English and Political Science.	Language.	Mathematics.	Drawing and Descriptive Geometry.	Mechanic Arts.	Military Tactics.
Professors.....(10)	1	1	1	1	1	1	..	1	..	1	2	..	..	..
Associate Professors(14)	3	2	..	1	1	1	1	..	3	1	1	..	..	..
Assistant Professors.(7)	..	1	1	1	1	..	..	1	..	..	1	1	..	..
Instructors .....(38)	2	5	1	2	8	5	1	1	2	2	3	2	3	1
Assistants.....(26)	4	6	..	..	4	4	1	..	..	..	1	3	3	..
Total.....(95)	10	15	3	5	15	11	3	3	5	4	8	6	6	1
Lecturers .....(14)	1	..	1	3	2	3	3	..	1	..	..	..	..	..
Total.....(109)	11	15	4	8	17	14	6	3	6	4	8	6	6	1

CHANGES IN THE FACULTY AND THE CORPS OF INSTRUCTORS.

In my report of a year ago, I announced the retirement of Prof. Wm. P. Atkinson from the chair of English and History, and his acceptance of the position of Professor Emeritus. To the deep regret of all his former associates and pupils, Prof. Atkinson died on the 10th of March, from an attack of apoplexy. The sentiments of the Corporation on the death of Prof. Atkinson have been expressed by a minute entered upon the records. I desire to add my personal tribute to Prof. Atkinson's devotion to the school, and his deep and tender interest in all his students.

Mr. George R. Carpenter has been appointed Associate Professor of English, entering upon his duties at the beginning of the school year.

Prof. Carpenter graduated from Harvard College in 1886, and was appointed Rogers Fellow for two years, 1886–88. The first of these years he spent in Paris, the second in Berlin, studying Comparative Literature. During the school year 1888–89 he was a member of the graduate department at Cambridge, continuing his studies and acting as assistant to Prof. Wendell. In 1889 he was appointed Instructor in English at Harvard, and served the University in that capacity throughout the year.

Prof. Carpenter is, as I have stated, especially a student of Comparative Literature; but with us he undertakes the difficult and delicate duty of giving to the students of a school of industrial science that instruction and practice in the use of language and in the art of composition which shall be most for their benefit, professionally and socially. The problem is a difficult one by reason of the limited amount of time and strength which, in an institution of high scientific and technical aims, can fairly be devoted to this object; but Prof. Carpenter takes it up with a zealous

interest which furnishes almost an assurance of success. His plan is to enter into such relations with the instructors in charge of the "professional" work of the school as will enable him intelligently to assign to each student themes having reference to his own studies, securing thus the great advantage of having the pupil write, simply, with direct intention, and out of a full mind, on subjects with which he is familiar and in which he is interested, instead of writing vaguely, affectedly, and ambitiously about subjects of which he knows little, and in which he perhaps takes but a slight interest. In the course of this work, lists will be made of students who display unusual aptitude and pleasure in composition; and these will be offered an opportunity for advanced study and practice in this line, so far as they may find time to undertake it. More important still, lists will be made of those students, beginning with the very first year, who, from lack of natural aptitude for such studies, or from defects of training, are found to be at a special disadvantage in English composition; and these students will be followed up with an unremitting but friendly importunity, to induce and enable them to correct their faults and supply their deficiencies on this side.

The problem of giving instruction in English, to the best effect, to students of scientific and technical schools, is a very interesting one. The teacher who shall solve it, will make a contribution to the philosophy of education which will be of great value, inasmuch as the number of these schools is large, and is rapidly increasing. The instruction given in English in the classical colleges is, by general admission, very unsatisfactory; but it, at least, stands related to the fact that the pupils have a comparatively large vocabulary, derived from long-continued work in language; that they have made a special study of etymology; that they have become familiar with the figures of rhetoric through the Latin and the Greek, and that they have for years been exercised upon subtile distinctions, alike in

language-study and in philosophy. Directly to introduce the methods of English instruction, as practised in our colleges, into a scientific school, would be to invite failure. Here the pupils have had little language-study; they are generally unfamiliar with the etymology of the words they use; they have little ingenuity in expression, and, indeed, but slight disposition to make much of expression, anyway. For pupils of this class, the methods that would be proper and useful in a college must be modified in no inconsiderable degree, if the highest success is to be obtained.

I have spoken of the deficiencies of the student of science, as compared with the student of the classics, of metaphysics, and of rhetoric, so far as the familiar college work in English is concerned. But it must not be thought that the account is all on one side. The scientific student has, to compensate for these deficiencies, certain mental qualities which may be made use of to good effect in training him to use his own language in statement, in narrative, in argument, or in the writing of personal letters and professional reports. The problem in pedagogics which I spoke of has reference to the best means of making use of those qualities in the teaching of English.

The student of natural and physical science has certain deficiencies in language which have been fairly acknowledged; but he has an immense advantage in a far greater clearness and vividness in the formation of mental images, and a much stronger grasp upon his conceptions. Trained, day by day and year by year, in the objective study of concrete things, he sees nothing vaguely; the images he forms are definite and distinct; what he knows, he knows perfectly. If fine writing be the end in view, these mental characteristics may or may not be advantageous; but for the purposes of simple, straightforward, manly expression, whether in description, in exposition, in narrative, in argument, or in business correspondence, they are a source of great power. Such a student will

still need much study and practice in the use of language to save him from committing numberless solecisms and to give him the completest use of his own powers of expression; but he is, taken altogether, not a whit less promising a student of English than his fellow in the classical college. Nay, the advantage indicated extends from the thinking to the speaking or the writing, since every word which is seen to contain a physical image, as so many words do, and indeed as nearly all words in their beginning did, means more to a student of science than to a student of language, literature, and philosophy.

It is my hope that Prof. Carpenter, taking up his work with enthusiasm tempered by good judgment, may be able so to organize the instruction in English at the Institute as at no distant period to solve the problem how to use, to the best advantage of the student, the limited amount of time which can be devoted to these studies and exercises in such a school as this.

Prof. Carpenter is assisted by Mr. Fred. P. Emery, who, in the past few years, has done so much to keep up and carry forward the instruction in English at the Institute, and who has shown a continual gain in power, both as a scholar and as a teacher; and also by Mr. R. W. Herrick, a recent graduate of Harvard, a young gentleman of excellent promise in literary work.

After a year's absence, Prof. Létang has returned, with renewed strength and zeal, to his duties in the department of architecture, cordially welcomed by all his former students.

The Corporation will learn, with deep regret, that Associate Profs. Holman and Schwamb have so far failed in health as to be obliged to give up their work for the current year. It is earnestly hoped that both these admirable teachers and highly accomplished scholars may be restored to us another year, in the full enjoyment of health. Each in his own line of work, Prof. Holman in physics and

especially in heat, Prof. Schwamb in mechanics and especially in machine design, has achieved a distinguished success, and has added much to the reputation of the Institute. Each is capable, granted only life and strength, of accomplishing still larger results.

In recognition of the increasing importance of the instruction in hydraulics, as well as of his own merits, Mr. Dwight Porter, Assistant Professor of Civil Engineering, has been appointed to be Associate Professor of Hydraulic Engineering.

Mr. Jerome Sondericker, for five years Instructor in Applied Mechanics, has been promoted to be Assistant Professor in that department. Prof. Sondericker graduated in 1880 at the University of Illinois, from the department of civil engineering. For three years he held the position of Instructor in Engineering and Mathematics in that institution, pursuing a course of graduate studies meanwhile. In 1883 he received the degree of C. E. from the University of Illinois, and was appointed Assistant Professor of Engineering and Mathematics. In 1885 he came to the Institute of Technology.

Mr. Eleazer B. Homer, for three years Instructor in the architectural department, has been appointed Associate Professor of Architecture. Prof. Homer graduated from the Institute of Technology in the department of architecture, with the class of 1885; and immediately entered the office of Messrs. Hartwell & Richardson, of Boston, where he remained until recalled to the Institute in 1887.

An important addition to the Faculty has been through the appointment of Dr. Harry W. Tyler as Assistant Professor of Mathematics. Dr. Tyler graduated from the Institute of Technology in the class of 1884, from the department of chemistry. He remained at the school two years as Assistant in Mathematics, and one year as Instructor. In 1887 he went abroad to carry on his studies at the University of Göttingen, and of Erlangen, at the

latter of which, in 1889, he received the degree of Doctor of Philosophy in mathematics, physics, and chemistry. He returned to the United States last year, anticipating an appointment in the mathematical department of the Institute; but was induced, by the urgent wishes of the Faculty and of the Executive Committee, to assume the duties of Secretary to the Faculty, then unexpectedly relinquished by Mr. Munroe. After a year's service in that capacity, Dr. Tyler received the appointment that has been mentioned. His accession greatly strengthens the mathematical staff, which now consists of two Professors, one Associate Professor, one Assistant Professor, three Instructors, and one Assistant. A brief survey of the work in mathematics done at the Institute may be of interest in this connection.

Our work in pure mathematics consists, on the one hand, of a limited range of subjects regarded as essential preparation for later technical work; on the other hand, of more advanced special subjects, open to students duly qualified.

In the former group, the ground to be covered is comparatively small, thus rendering possible a considerable degree of thoroughness and facility in operation. In view of the large number of students to be dealt with, the necessary drill requires a subdivision of each class into a considerable number of sections. Thus, in the first year, the class in mathematics numbers about three hundred and twenty, and is divided into twelve sections; while any material increase in the size of the class would render a still greater number of sections necessary. These sections require together forty-eight to sixty hours of instruction per week.

The second-year class in plane analytic geometry and differential calculus numbers about two hundred and forty students, grouped in ten sections, by courses: for these, thirty hours of instruction are required per week.

The series of required mathematical subjects terminates, in general, with integral calculus, for which a class of one hundred and sixty is divided into eight sections, receiving a weekly average of twenty-one and one-third hours of instruction during half of the third year.

Each student in an engineering course is thus expected to attend, during two and one-half years, 260 mathematical exercises, as follows: algebra, 32; solid geometry, 28; plane and spherical trigonometry, 70; plane analytic geometry, 45; differential calculus, 45; integral calculus, 40. With the present preponderance of the engineering courses, about 90 per cent of the graduates in any year will have completed the above series. Of students in the Institute at a given time, about 80 per cent in the first term, 60 per cent in the second term, are pursuing some one of these subjects.

The mathematical subjects of the second group, although they claim naturally a relatively small number of students, are of vital importance for the course in physics, and exert, as an admixture of pure science, a highly salutary influence on the technical work of the Institute. Besides the subjects now offered in the Catalogue, viz., General Theory of Equations, Determinants, Advanced Algebra and Trigonometry, Analytic Geometry of Three Dimensions, Advanced Calculus, Differential Equations, Theory of Probability and Method of Least Squares, and Quaternions, still more advanced courses may in time be arranged for graduate students in physics. For work of this character, a working-library is indispensable. The nucleus of such a library already exists in the general library of the Institute. By the courtesy of Prof. Richards, space for a needed mathematical reading-room has been placed temporarily at the disposal of the mathematical staff.

An addition to the corps of Instructors not of Faculty rank, upon which we may greatly felicitate ourselves, is found in the appointment of Dr. Augustus H. Gill, of the

class of 1884, Dr. Henry P. Talbot, of the class of 1885, and Dr. Arthur A. Noyes, of the class of 1886, as Instructors: Dr. Gill, in gas analysis, Drs. Talbot and Noyes, in analytical chemistry. These young men were among the strongest scholars of their respective classes while students at the Institute, and remained with us, as Assistants or Instructors, until their departure to pursue advanced studies in Germany. Returning with well-won honors, they have resumed work in the chemical department under the most favorable auspices.

Mr. James H. Stanwood, of the class of 1887, who for two years has been an Assistant in Civil Engineering, has been appointed Instructor. Mr. Collier Cobb, of the class of 1889, in Harvard University, and last year Assistant in Geology there, has been appointed Instructor in Geology. After the school year had been in progress two months, the sickness of Prof. Schwamb suddenly required the services of an additional Instructor. The Executive Committee were fortunately able to obtain the assistance of Mr. Edward V. French, of the class of 1889, who was appointed Instructor. This re-enforcement, together with the appointment of an additional Assistant during the second term, will, it is hoped, enable Profs. Lanza and Peabody to carry the heavy load so suddenly thrown upon them.

SUMMER SCHOOLS.

Summer School in Geodesy and Topography.— This school was held during the past summer at South Deerfield, Mass., and was attended with marked success. The instructors were Prof. Porter, Mr. Robbins, and Mr. C. C. Babb, of the class of 1890. The school covered a period of three weeks. Owing to the necessary absence of Prof. Niles, geology was omitted from the course this year, and the time thus left vacant was devoted to work in topography, geodesy, and hydraulic measurements. Several complete gaugings were

made of the flow of the Connecticut River, and the work thus done served as a valuable relief in the regular work, belonging to the fall term, of gauging the Charles River. Indeed, had not a portion of the class already had this experience in their summer course, it would have been impossible to carry on the hydraulic measurements during the present term without additional assistance. Ten students were in attendance on the summer school, most of them members of the present graduating class. All manifested a gratifying degree of interest and enthusiasm. The summer course has now been carried on for three successive years, with constantly increasing success.

The Summer Mining School. — During the month of June, twelve students attended the summer school of mining, which was held at the mines of the Lake Superior Iron Company, Ishpeming, Mich., under the direction of two professors. The study had special reference to practical mining work.

The class was divided into three parties, each working for a week in one special line, thus alternating during three weeks in three departments, viz., practical work underground, survey underground, geology and survey aboveground.

The practical work underground consisted of drilling, blasting, timbering, hauling, and prospecting with the diamond drill.

The underground workings are so extensive that the successive surveying parties were able to start from different levels, passing through different winzes or stopes downward, and to come back each another way and connect with the starting-point, thus closing the survey.

Aboveground the work consisted in mapping the surface with the plane table, studying at the same time the geology. By comparing the surface-map, obtained with the company's maps of underground workings, and adding the data from the diamond-drill records, which were kindly

furnished, a very satisfactory geological section was made across the entire basin.

The party was much indebted to Mr. J. S. Fay, Jr., the treasurer of the company, to Mr. C. H. Hall, the general manager, to Messrs. Chipman and Sturtevant and other officers of the company.

In addition to the regular work at the Lake Superior mines, three excursions were made, on as many days, to the Barnum mine at Ishpeming, the Jackson mine, charcoal-kilns and charcoal-furnace at Negaunee, and the Ropes gold mine and mill, about six miles from Ishpeming.

The party was everywhere warmly received, and thanks are due also to other mine managers, whose kind invitations to visit them could not be accepted, owing to lack of time. One section of the party made an excursion to Marquette, to visit the great shipping docks there.

Course I. *Civil Engineering.* — The course of study in this department has been somewhat modified this year. The time devoted to railroad management has been increased, and the course is now taken only by students choosing the railroad option; while the course in hydraulic measurements is now taken only by students choosing the general-engineering option.

Some additions have been made to the stock of surveying instruments; but, with the increasing number of students, further expenditures in this direction will soon be imperative. The new hydraulic tank described in my last report has within the past year been fully connected with the stand-pipe and with the pumps, and the entire apparatus is now complete in its main features. A great deal remains to be done, however, in providing accessory apparatus for carrying on the experiments and investigations with which the hydraulic laboratory was designed to deal. A brass casting, fitted with several orifices of various shapes and sizes, has been made by the Hancock Inspirator Company, and was in use last term, so that we are

now prepared to carry on experiments upon the flow through simple orifices. At the present time some gates and rigging for closing the orifices are under construction, and plans are being prepared for apparatus designed to serve in carrying out the various lines of experiment specified in my last report, such as the flow through mouthpieces, over weirs, and through pipes, experiments touching the losses of head under various conditions, the distribution of velocity in pipes and jets, the siphonage of traps, and many other problems.

The development of these lines of research and experiment will necessitate the construction of various pieces of apparatus, accurately made of brass, which are somewhat expensive. As much as is possible with the means at command will be done this year; but without largely increased resources, the department can not hope to extend and diversify its instruction as far as would be desirable. Several thousand dollars should be expended during the next few years in building up this laboratory. We have now a system of tank and stand-pipes, forming a basis for hydraulic experiments, which is unapproached. None of the great technical schools of Germany, so far as is known, have anything to compare with this; and the technical attaché of the German Legation in Washington, in visiting our laboratory last year, was so impressed that he requested drawings of the entire hydraulic apparatus to send to his government. It is to be hoped that the development of this laboratory, on the grand foundation already laid, will be pushed as rapidly as is practicable.

Progress has been made in the printing and lithographing of lecture notes, by the addition of Prof. Allen's notes on railroad engineering, Prof. Porter's notes on stereotomy, and some additional notes and detail drawings of bridges. The engineering library has been materially enriched during the past year by the addition of a number of valuable works, and by several complete files of period-

icals. It is rapidly becoming a valuable working collection. Upwards of sixty technical periodicals are now regularly received in this library.

Mention should be made of the fact that the Messrs. Parker & Parker, of Boston, have kindly loaned to the department, for an indefinite time, one of their four-inch Berrenberg rotary pumps, for use in the hydraulic laboratory; also that the Tuerk Motor Company have loaned one of their motors for experimental purposes. The department has also received from the Westinghouse Air Brake Company a triple valve of the newest type, showing its internal construction.

Highway Engineering. — Special progress is being made in the development and extension of the instruction in highway engineering. Through means furnished by Col. Albert A. Pope, of Boston, the regular instruction in this branch will be considerably extended; additional lectures will be given by outside engineers specially engaged in this class of work; the outfit of the department in the way of books, models, drawings, specifications, etc., will be at once largely increased; apparatus will be provided for tests of all kinds of road materials; and every effort will be made to carry the instruction in this branch as far as is consistent with its necessary relations to the other studies in the course. That development must take place slowly, and for a time, tentatively, in the directions which experience shall show to be most profitable. This year the amount of time given to the regular instruction will be doubled; some outside lectures will be given, charts and drawings will be prepared on a considerable scale, and means will be taken during the summer for gathering a large amount of additional material and information at home and abroad.

The demand for graduates in civil engineering has this year been greater than ever before, the number of graduates in the last class being much smaller than the number of positions offered. One of the graduates, Mr. C.

W. Sherman, has returned this year, to pursue advanced courses of study.

Course II. *Mechanical Engineering.* — In my report of December, 1889, the new Engineering Building and its equipment were fully described ; but at that time the laboratories and drawing-rooms of the mechanical engineering department were still in the Rogers Building. The removal took place just before the beginning of the second term in February, 1890. Notwithstanding the difficulties incident to transferring so large an amount of machinery and other apparatus during term time, and putting it in order for use, both in the regular laboratory practice and in the work of research pursued in connection with the theses of the fourth year's class, and notwithstanding a very annoying delay in the transportation from Milwaukee of the new triple-expansion engine, the exercises in this department were resumed promptly at the beginning of February, and were carried on without interruption through the remainder of the school year. But for the new building, it would have been impossible for the department to perform its regular laboratory work of the second term, owing to the increase in the number of students.

By way of addition to the present equipment, the most important thing of which these laboratories stand in need is an Emery testing machine of at least 200,000, better still of 300,000, pounds capacity, such as are now made by Wm. Sellers & Co., of Philadelphia. This machine would enable the applied-mechanics laboratory to perform work of great importance, which it cannot now undertake.

In addition to the natural development in all parts of the course, it should be mentioned that the work in naval architecture has already increased to such an extent that, instead of devoting to it a portion of time allotted to marine engineering, there is to be given the present year a course of two exercises per week on this subject, extending throughout the second term of the fourth year ; and those students

who take the marine-engineering option are to be given a choice, in addition, of taking either this course on naval architecture or the course on hydraulic motors.

The work in naval architecture is to be carried on by Prof. Peabody, with such additional assistance as it is hoped to obtain from Naval Constructor J. J. Woodward, or Naval Constructor Armistead.

The publication of the new and enlarged edition of Prof. Lanza's "Applied Mechanics" will afford a great help in carrying forward the instruction in this important branch of study, which so largely underlies nearly all the professional work of the school. For several years, now, the amount of cyclostyled notes and tables with which the students of applied mechanics have been furnished, in addition to what was contained in the text-books, has constituted an increasing burden. All this material has been incorporated in the revised edition, to the great relief of our classes.

Course III. *Mining Engineering and Metallurgy.* — This course has been wholly recast in form and not a little altered in substance during the present year. For reasons which will appear in speaking of the new Course XII., the department of mining engineering and metallurgy has been disconnected from all relations to the geological instruction of the Institute, except such as are for the benefit of its own students; and geology has been provided for in a separate course. The mining department, thus relieved from much that has been a burden to it, has been enriched by the addition of a great deal in the way of mechanical and civil engineering, which the present demands of practice made it important that the mining engineer should possess. Course III. thus, on the one hand, relieved from a burden it has carried in the past, and enriched and strengthened by more of properly engineering work, has been recast into four lines, which, for the further purposes of this paragraph, I may call "courses." Of these, the first

course prepares a student to take hold of work in line for promotion in any mining industry, — coal, iron, gold, silver, copper, or lead, — as a miner, a foreman, assistant manager, or manager of a mine. It fits him in geology, mining, milling, and in mechanical engineering adapted to mining. The second course prepares a student to take hold of work in line for promotion in a surveyor's office in a mining district as assistant surveyor, as surveyor of mines, as consulting mining engineer, as mine superintendent. It fits him in geology, mining, milling, and in civil engineering adapted to mining, construction of railroads, electric railroads, canals, roads, buildings, bridges, etc. The third course fits a student to take position in line for promotion in an iron, lead, copper, zinc, gold, or silver works as a hand, as foreman, assistant superintendent, or superintendent, or he may enter the works by the chemical laboratory. It fits him in analytical chemistry, metallurgy, mathematics, and in mechanical engineering adapted to metallurgical machinery, blowing engines, rolling mills, etc. The fourth course fits a student to take position in line for promotion in an iron, lead, copper, or zinc works as assistant chemist, as chemist, as furnace manager, as superintendent. It fits him in analytical and theoretical chemistry, in metallurgy, in electro-metallurgy.

The equipment of the milling-room has been increased during the year by adding an independent engine for running the machinery. There has been received from Messrs. Frazer & Chalmers, and Joshua Hendy Manufacturing Company, and from F. A. Huntington, the following machinery, a new Vanner, a new stamp battery, a new Hendy feeder, and a Huntington mill, at figures so low as to be practically a gift.

The amalgamating plant has been extended by the addition of four iron and three copper amalgamating pans, suitable for a great variety of tests, adding greatly to the capacity of the laboratory for teaching this subject.

The changes in the furnace-room include the reconstruction of the cupellation furnace, so that it can now be also used for smelting and refining small batches of copper, giving the students excellent facilities for becoming familiar with the higher heats necessary for copper smelting, and the placing of a hood in front of the blast furnace, which removes nearly all the fumes. A Brückner roasting cylinder is contemplated, and a place has been provided for it.

Course IV. *Architecture.* — In the architectural department the most important fact of the year has been the notice given of the suppression of the Two Years' Partial Course, to take effect in 1891, placing this department, at last, upon precisely the same basis as to regular and special students, with all the others. This will not keep away the class of pupils who at present constitute the main strength of the partial course, since it is intended to allow students to enter the departments as special students who have had two years' regular office experience, or who are graduates of colleges, or are over twenty-four years of age, to pursue such studies as they may be fitted for, these candidates being required only to pass a thorough examination in mechanical and freehand drawing, for entrance.

The regular course of studies has been rearranged and strengthened to meet this improvement. Graphical statics, at present only taught in theory, is to be applied to actual construction; and this very important application will be carried through an entire term. In the fourth year there have been added courses in sanitary science, history of construction, history of the Renaissance, and history of painting and sculpture. The library is now in first-rate working order, and, with a small yearly outlay, can be kept up very satisfactorily.

During the year there has been presented to the department a valuable set of working plumbing models by Messrs. William Lumb & Co., of this city; by Mrs. Edward M. Cary, a rare architectural work, Monuments of Art, by

Lubke & Caspar; and by Mrs. Emma L. Metcalf, a very interesting collection of drawings of the stained-glass windows of the Cathedrale d'Auch.

A very gratifying expression of the good-will of the class graduating from the architectural department in 1890 took the form of a sum of money, $102.25, subscribed by them as a token of their interest in the "assured welfare and progress of the department, to make some slight addition to the resources of the school for the benefit of those who shall come after." With this money was bought the splendid work of Prisse d'Avennes, *d'Art Arabe*, making a most notable addition to the library.

The greatly increased number of students in this department will speedily render necessary an increase in the instructing staff. Considerable appropriations are also required for the construction of diagrams illustrative of the various courses of lectures, so that the instructors may be released from the loss of time now involved in putting their designs upon the black-board afresh each time a lecture is repeated.

Course V. *Chemistry.* — By a vote of the Executive Committee, Prof. Thomas M. Drown, Perkins Professor of Analytical Chemistry, has been placed in charge of the entire chemical department of the Institute. The work of the year in general chemistry and in analytical chemistry has gone on fortunately, without any notable change. The appointment of Dr. Gill, already spoken of, puts it in the power of the department to carry instruction in gas analysis much further than it has ever before been sought to do. At present, this service occupies, with a fair supply of apparatus, a small part of room 33, New Building; but it is in contemplation to enlarge the space devoted to this work, and to add a considerable amount of new apparatus. It is not alone the students of the chemical department proper who derive benefit from this branch of analysis, but also the chemical, mechanical, and mining

engineers, who have here the opportunity of becoming familiar with the methods of analysis of furnace gases.

The analysis of the waters of Massachusetts for the State Board of Health still continues to be carried on in the department of sanitary chemistry. The volume covering the results of two years of this work, together with a discussion of their significance regarding the public health, is now in press, and will shortly be issued by the Board. It is safe to say that this will be the most valuable contribution to our knowledge of natural waters that has ever been made in this country.

The crowded condition of the laboratory of organic chemistry made it absolutely necessary to find more room somewhere, somehow; and room 33, New Building, was fitted up as a supplementary laboratory for organic analysis and research.

The work in industrial chemistry has been steadily carried forward during the year. It is here that the Institute most needs powerful re-enforcement to enable it to do its largest service to the industries of the Commonwealth. With our present means, we can only make progress slowly in this all-important department. Twenty thousand dollars a year might advantageously be spent in these laboratories alone, above all which the present means of the Institute can provide; and if this were judiciously done, the industries of the State and the country would reap the proper fruit of such expenditures an hundred-fold.

In one respect, the laboratories of industral chemistry have undergone a notable development during the year. Inasmuch as the space given to textile coloring was insufficient, and the light in the basement where the instruction was given was less than satisfactory, the Executive Committee decided to use room 31, on the third floor of the New Building, for a laboratory for textile coloring. The necessary changes were made during the summer, and the laboratory was opened to the students, Oct. 1. The

room is fitted with appliances for experimental dyeing, and can accommodate a class of ten at a time. The laboratory is equipped with sixty jacketed pots, heated by high-pressure steam. The pots are constructed according to plans prepared by the Instructor, Mr. J. W. Smith, are novel in form, and furnish most excellent results. All the apparatus used in textile coloring, including the printing machine, steam-box, and dye-baths, has been removed to this room.

The course in textile coloring has been still further developed during the year, and it is believed that it is now one of the most complete laboratory courses given upon this topic. In connection with the laboratory work, lectures are given and excursions made to textile works. The course is taken by seventeen students, and is to be regarded as a valuable adjunct in a general chemical training. It is further specially adapted to the needs of those students who intend hereafter to follow textile coloring, and to furnish them with a suitable scientific basis for their subsequent work, and even to fit them for subordinate positions in dye works, where they can then obtain intelligently the practical experience indispensable to the dyer and colorist.

It is much to be desired that still another room on this (the third) floor of the Clarendon Street Building should be devoted to special chemical investigations ; but, with the many urgent demands from several different quarters for increased accommodations, it does not now seem possible to do more for the department of chemistry.

Course VI. *Electrical Engineering;* and **Course VIII.** *Physics.* — There is little to record with reference to these courses beyond a continuance of the steady growth in efficiency and in number of students which has been recorded in previous years. Most of the graduating theses embodied results of really original work, and several have been published, or will be shortly.

There has been a gradual extension of the work in the

physical laboratory, especially in electrical measurements; and during the present year, with the co-operation of the department of mechanical engineering, it is expected that much more will be done than heretofore in connection with the testing of dynamo-electric machinery, for which the facilities of the engineering laboratory are fully available. The general outfit of the physical laboratory is excellent, and has kept pace with the improvement in apparatus for physical measurement.

The most important change in the general scheme of instruction is one whereby the professional work in electricity of the students in Courses VI. and VIII. begins earlier than heretofore in the second year, which will, it is hoped, give more time in the latter part of the course for considering some of the newer developments of technical electricity. It is also proposed to give a brief course of lectures on physical measuring instruments to students of Courses VI. and VIII. in the second year, before entering the physical laboratory, the course to be in charge of Mr. Goodwin, Assistant in Physics.

The increasing number of courses which the department gives, both to its own professional students and to others, and especially the development of the courses in heat measurements, and electro-metallurgy, mentioned in the President's last annual report, will necessitate additional assistance during the coming year.

Owing to the much-regretted absence of Prof. Holman, on account of illness, two additional Assistants, Messrs. Swanton and Smith, have been specially appointed to aid in the work of the laboratory, in addition to Mr. Goodwin, previously appointed Assistant. These, with Messrs. Puffer and Collins, Instructors in Physics, and Mr. Laws, Assistant, are working very faithfully to maintain the excellence of the instruction in the laboratory, while Mr. Clifford has successfully completed the course of lectures on heat to the third-year students, usually given by Prof. Holman.

The extensive calls made upon this department for electricity to be used for general electric lighting within the Institute, and for furnishing power to various departments, will, if these continue to increase, require a larger supply of driving force than we have at our command; and, indeed, our engine of seventy-five horse-power is already at times taxed nearly to its maximum. During a considerable period, this term, the ventilating fan for the New Building has been driven by electricity, an electric motor replacing the steam-engine when this was temporarily disabled.

A growing difficulty has been met with on account of serious jarring of the building. This, always considerable, has materially increased of late with the increased use of the neighboring streets, by cars and teams. Some of our thesis work, involving the use of delicate measuring instruments, has had to be done in the night, in order to obtain satisfactory results; and it is very questionable whether certain experiments must not be omitted from the regular course of instruction, for the same reason. This difficulty cannot be removed; but it may perhaps be possible to mitigate it by the use of piers and supports of special construction.

There is also a pressing need of more room for laboratory and class instruction. For several years past it has often been found impossible to obtain a room which would comfortably seat our professional classes, and much inconvenience has been caused thereby. There is, furthermore, a need of several small rooms, which can be allotted to optional advanced laboratory work, the character of which renders it very difficult to carry it on among the distractions which are necessarily felt in a large room occupied by other students.

Course VII. *Biology.* — The number of regular students in this department, as well as of those turning to this department from the chemical, architectural, engi-

neering, and general courses, for instruction in special subjects, steadily increases. With the beginning of the present year the staff was strengthened by the appointment of Mr. George V. McLauthlin, a graduate of the Institute in the chemical department in the class of 1888, as Assistant in Biology. This addition to the force has resulted in an extension and improvement of the courses in comparative zoölogy, anatomy, and embryology, by enabling Dr. Gardiner to devote his whole time to these subjects. This portion of the work of the department is now in a satisfactory condition.

Prof. Sedgwick continues to give the instruction in general biology, microscopy, botany, and physiology. But the relations of biology to sanitary science are manifestly so fundamental and far-reaching in their practical bearings that sanitary biology and bacteriology also claim a large portion of his time and energy. The recent remarkable extension of our knowledge of the ætiology of the infectious diseases has already made bacteriology one of the most important as well as one of the most practical of the biological sciences. Already the biologist has taken his place side by side with the chemist and the engineer in the study of the science and art of public sanitation. During the past year the biological work of the Lawrence Experiment Station of the State Board of Health has been done in the biological laboratory of the Institute, under the personal superintendence of Prof. Sedgwick, who has been ably assisted by Mr. Edwin O. Jordan, a graduate of the biological department in the class of 1888. Their reports to the Board, which are believed to constitute contributions of the first importance to sanitary biology, are already in the press.

The acknowledged importance of normal bacteriology, not merely in sanitary science, but in engineering, chemistry, and agricultural science, makes it imperative that this school shall not lag behind in the discoveries and their

applications already opening before us. The activity of soils, the fixation of nitrogen, the preservation of foods, the preservation of timber, the purity of public supplies, such as air, water, milk, and ice, as well as the more urgent and difficult problems of drainage, sewerage, and the public health, are obviously questions of immediate practical importance. To meet these new demands, the biological department should be strengthened by ampler accommodations, and the freeing of the professor in charge from much of his present elementary instruction.

Of the three persons graduated in biology in 1890, one submitted as his thesis important original results of an investigation of the bacteriological condition of the milk supply of Boston, soon to be published; the second, a young woman, was appointed, before graduation, teacher of science in a collegiate preparatory school; the third, after spending the intermediate time in the further study of bacteriology in Berlin, has been appointed to an important position in the service of the State Board of Health. The department this year has been unable to meet one-third of the demands made upon it for its graduates.

Course IX. *General Studies.* — I have already, in connection with the appointment of Prof. Carpenter, spoken of the plans that have been formed for extending the study of English at the Institute. The department of history has shared in the general prosperity that has attended Course IX. during the past year. The increased accommodations and the very convenient rearrangement of the departmental library and reading-room have enabled students to use their tools of labor, viz., books, papers, and magazines, with much better effect and understanding than ever before. The system of historical and political studies by means of class reference-libraries is now applied here under unusual advantages. The undergraduate student enjoys a daily use of all the necessary works of reference and literature on his subject, — a use which is rarely both con-

venient and possible to any but graduate students. Some considerable additions to the resources of the department have been made, including wall-maps, books of reference, and sets of reviews for political and library study.

During the last year a paper from this department, on the history of the Northeastern Fisheries, was published in the "Technology Quarterly." A graduate student from Course IX., Mr. Wm. B. Thurber, obtained last spring the degree of Master of Science, as the result of one year's advanced study, mainly under the direction of the department of history.

The accession of Prof. Carpenter to the chair of English has not only enabled Course IX. to extend and strengthen the literary side of its curriculum, but has also permitted the department of history to increase the time devoted to the history of philosophic thought, a field of study which is at present intrusted to the care of that department. The increase in the number of students in Course IX., and the very gratifying interest in history study shown by members of other courses in the Institute, will undoubtedly compel the department, at no distant day, to ask for additional assistance. The instruction in economics and statistics heretofore given has been continued with marked success during the year.

The instructors in the department of modern languages would gladly join with those of English, history, and economics in promoting the success of Course IX.; but no more can be done on this side without an increase of the instructing staff. All the teachers of modern languages are now fully occupied with their classes; and still those classes are larger than we could wish. For the best effect, it would be desirable to reduce the sections in French and German to the same size as the mathematical sections. This reduction could be effected by the assistance of two additional instructors, making the modern-language staff six, instead of four, as at present. That

increase would also allow of considerably more advanced work in French and German, for the benefit of graduate students, of students in Course IX., and also of students of other courses who should be ambitious to perfect themselves in these lines. It is clearly for the interest of the school as a whole, and of the professional courses as well, that modern-language study should be encouraged to the full extent of our means. The teachers in German are this year making a special effort to promote the readier reading of scientific and technical works in that language. Prof. Luquiens has undertaken the class in Spanish which last year was taught by Mr. Machado.

Course X. *Chemical Engineering.* — The first students in this course will be graduated in 1891. During the present year, instruction is being given for the first time to students of the fourth year. During the first term the instruction is mainly in mechanical engineering and in applied mechanics. The time devoted to chemistry is given to gas analysis and to laboratory work in applied chemistry, and to a new course in which various engineering problems are discussed from a chemical point of view. The leading topics considered in this course are fuels, their composition and consumption, boiler waters and incrustations, corrosion of boilers, lubricants, and other similar questions. This course will be followed in the second term by a course of lectures in which chemical machinery will be considered from an engineering point of view.

During the year a course in gas analysis, including the analysis of furnace gases and illuminating gas, has been instituted, mainly for the benefit of the students of chemical engineering, under the direction of Dr. A. H. Gill. The apparatus used for this purpose has been increased, and the course will be further developed during the coming year. An optional course in hydraulics, including the consideration of hydraulic motors and field measurements, has also been introduced during the past year.

Course XI. *Sanitary Engineering.* — No changes of importance have this year been made.

There are now seven regular students in the third year of this course, who next year will be candidates for the degree of the Institute.

Course XII. *Geology.* — Heretofore the teaching of geology and mineralogy has been made subsidiary to some of the established courses. During the past year a distinctly geological course has been added, with features worthy of special mention.

A notable departure from the usual courses in this science is the prominence given to topographical studies in connection with geology. The advance of improvements, wealth, and population is increasing the need of more detailed and careful surveys, even of the best known portions of our country. Too frequently, topographic maps are unsatisfactory to the working geologist, partly from their having been constructed by men who have not understood the significance and relative values of the features they have attempted to represent. There has accordingly arisen a demand for men qualified to perform superior work, both in topography and in geology. In recognition of this need, there has this year been inaugurated at the Institute a geological course, with much stronger topographical requirements than is usual.

The Institute of Technology has peculiar advantages for carrying on such a course. It already possesses a strong department of civil engineering, prepared by its equipment and corps of Instructors, including a special Professor of Topographical Engineering, to give to the instruction in topographic, geodetic, and hydrographic surveying that practical and thorough character which is desired.

That the institution presided over during its early days by Prof. Rogers should conspicuously cultivate the study of topographical geology seems highly appropriate, when we remember the eminence its founder and first Professor

of Geology attained, by unfolding the elaborate structure of the Appalachian Mountains and their resulting topography.

The new geological course contains a substantial amount of work in the construction of geological maps and sections, in physiographic geology, including orography, and in hydrography, besides large additions to the field-work heretofore provided for, together with the requirement that the students shall attend the summer course of topography and geology in the field.

Another important feature of the course provides for the application of geological knowledge to the discovery and development of mineral resources. Following the general chemistry of the first year, the student has analytical chemistry through his second and third years, qualifying him for assaying, and for work in mining and metallurgy, which he may elect in his fourth year. To the general courses in dynamical, structural, and historical geology and in mineralogy, there are now added advanced mineralogy, micro-lithology, and ore deposits. One of the most important additions is a course in economic geology, extending through the fourth year. These branches, with the study of geological maps and sections, already mentioned, and a liberal amount of field-work prepare the student to further specialize upon either chemical, lithological, or economic geology.

The Institute occasionally receives students who desire a thorough course in geological study without reference to any technical profession. Sometimes these students are well-qualified women, studying with well-defined purposes. When such students present good reasons for desiring more paleontology, zoölogy, and biology, arrangements may be made, by vote of the Faculty, for substituting such studies for certain others.

FINANCIAL.

The additions made since my last report to the funds of the Institute, as appears by the report of the Treasurer, are as follows: —

By bequest of the late George Bucknam Dorr, applied to the general purposes of the Institute	$49,573 47
By bequest of our late lamented colleague on the Corporation of the Institute, Hon. Charles Lewis Flint: —	
As a Scholarship Fund	5,000 00
As a Library Fund	5,000 00
By bequest of the late Elisha Thacher Loring, as a Scholarship Fund . .	5,000 00

Through the death of Miss Susan C. Dorr, the title of the Institute of Technology to two-thirds of the estate in Lenox, Mass., known as "Highlawn," became absolute, subject to the provision contained in the deed of gift of Mrs. Martha Ann Edwards, dated Nov. 21, 1876.

By Miss Dorr's will, the Institute is given an interest, of an as yet undetermined amount, in her own estate.

By the will of the late Samuel E. Sawyer, of Gloucester, the sum of $4,000 was bequeathed to the Institute of Technology. This will is being contested by the heirs of Mr. Sawyer.

Besides the foregoing, a prospective addition to the means of the Institute is seemingly furnished by the provision of the Act of Congress, approved Aug. 30, 1890, "for the more complete endowment and maintenance of Colleges for the benefit of Agriculture and the Mechanic Arts now established, or which may be hereafter established in accordance with an Act of Congress approved July 2, 1862"

Of the income of the fund created within the State of Massachusetts by the provisions of the Act of July 2, 1862, above referred to, the Institute of Technology was, by the Act of the General Court, approved April 27, 1863, allowed a one-third share, the remaining two-thirds being allotted to the Agricultural College at Amherst. Our share of this fund has yielded last year, as will be seen by the Treasurer's report, the sum of $4,960.82.

Whether or not the provisions of the State law of 1863 will operate to authorize the Governor and Council of the Commonwealth to apportion the new grant, without further legislation, is at present under consideration at the State House. If the existing legislation is sufficient to allow the apportionment of the new grant, the Institute of Technology will of course receive one-third of the annual appropriation from the national treasury, amounting for the present year to $5,000; to rise yearly by the sum of $333⅓ to a maximum of $8,333⅓ in 1900 A. D.

Should it be decided that new legislation is needed to enable the Commonwealth to avail itself of the grant from the treasury of the United States, I recommend that the Corporation authorize its officers to memorialize the General Court, at the approaching session, to award to the Institute of Technology, as the College of Mechanic Arts for the State of Massachusetts, a larger share of the annual income thus to be received from the General Court.

At the time the Act of April 27, 1863, was passed, the Institute of Technology existed only upon paper. Its future was necessarily involved in grave uncertainty. The person then most confident of success could not possibly have anticipated such a development of its influence as has taken place. It might not unreasonably have been anticipated that its students would always remain few, and that its relations to the industries of the Commonwealth would be narrowly restricted within the familiar limits of civil engineering, and perhaps also of chemistry. Under the

circumstances, the proportions established by the Act of 1863 — two-thirds to the Agricultural College, one-third to the Institute of Technology — may be regarded as not unfair.

Within the twenty-seven years that have elapsed since the date of the Act referred to, however, this School of Industrial Science has grown into dimensions then inconceivable, and it has connected itself with the industrial life of Massachusetts in ways then unknown. Professions not named in 1863 have come into being, and have risen to transcendent importance, while the development of industrial science throughout the world, to which no single institution has contributed more than this our own school, has created demands which were not then felt. If Massachusetts would hold her proud pre-eminence in manufactures, she must do it by force of knowledge and technical skill, since her natural disadvantages in respect to transportation and the possession of the materials of production are weighing all the time more and more heavily against her. The Institute of Technology is, in spite of its large tuition fees, still painfully poor in relation to its needs. Without disparagement to any, it may be said that in no other way can Massachusetts so largely aid herself as by increasing the means of this institution available for chemistry, mechanics, and electricity.

TREASURER'S REPORT.

STATEMENT OF THE TREASURER.

The Treasurer submits the annual statement of the financial affairs of the Institute for the year ending Sept. 30, 1890.

During the year the executors of the estate of the late George Bucknam Dorr have handed over to the Institute the following securities at the valuation set against each:—

International & Great Northern R. R. Bond	$1,110 00
Milwaukee & St. Paul R. R. 7 8/10s, $3,000	3,510 00
Chicago, Burlington & Quincy R. R. 7s, $7,000	8,715 00
Cincinnati & Indiana R. R. 7s, $2,000	2,080 00
Union Pacific R. R. 1st Mortgage 6s	1,140 00
Chicago, Burlington & Northern R. R. 5s, $2,000	2,060 00
Atchison, Topeka & Santa Fé R. R. 4s, $2,000	1,687 50
Atchison, Topeka & Santa Fé, Incomes, $500	301 88
Chicago, Burlington & Quincy R. R. Stock, 14 shares	1,477 00
Pittsburgh, Fort Wayne & Chicago R. R. Stock, 20 shares	3,000 00
Morris & Essex R. R. Stock, 82 shares	6,150 00
New York & Harlem R. R. Stock, 40 shares	5,000 00
Pennsylvania Coal Co. Stock, 75 shares	11,250 00
Consolidated Gas Co. of N. Y. Stock, 15 shares	1,447 50
Cash	644 59
	$49,573 47

By the decease, Dec. 5, 1889, of Miss Susan C. Dorr. the title of the Institute to two-thirds of the estate at Lenox, Mass., known as "Highlawn," became absolute, subject, however, to the provision named in the deed of gift of Mrs. Martha Ann Edwards, dated Nov. 21, 1876.

Under circular 63 of Oct. 15, 1889, of the Atchison, Topeka & Santa Fé R. R., sundry bonds of former issues were exchanged into the present general mortgage four per cent and income five per cent bonds. The amount of bonds included in this exchange appears in the General Statement on the following pages.

The estate 1004 Walnut Street, Philadelphia, has been sold by the executors of the estate of Robert E. Rogers, producing for the interest of the Institute in the same $990.48 more than the valuation entered on our books.

The income has been divided at the rate of $4\frac{735}{1000}$ per cent among the funds to which it belongs.

Gifts and bequests have been received from : —

State of Massachusetts	$50,000 00
Subscription of 1887	36,000 00
Charles Lewis Flint, to found Scholarship Fund . .	5,000 00
" " " " Library " . .	5,000 00
Elisha Thacher Loring, " Scholarship " . .	5,000 00
Mrs. Wm. B. Rogers, for periodicals	100 00
From a Friend, for Engineering Instruments . .	500 00
Alumni of Institute towards Wm. B. Rogers Scholarship Fund	2,000 00

The net result of the year has been an expenditure over receipts of $3,216.38, which has been charged against Massachusetts Institute of Technology Account.

LEWIS WILLIAM TAPPAN, JR., TREASURER, *in account*

GENERAL STATEMENT OF RECEIPTS AND DISBURSEMENTS

Dr.

Cash balance Sept. 30, 1889		$26,570 12
From Augustus Lowell for Lowell Courses	$2,500 00	
" " " " C. Kastner's salary	2,500 00	
" " " " Lowell School of Design	1,000 00	
		6,000 00
RECEIPTS FOR CURRENT EXPENSES.		
Income of funds for salaries	$4,147 86	
" " " " scholarships	2,916 49	
" " " " library	177 58	
" " " " general purposes	8,276 66	
" " Rogers Memorial Fund	12,511 25	
" " Joy Scholarship Fund used	200 00	
" " Susan H. Swett " "	125 00	
Students' fees	170,442 65	
State Agricultural Fund	4,960 82	
Boston University	1,150 00	
Laboratory breakage and supplies	4,566 51	
Rents, per Table. (Page 12)	5,342 50	
Gifts	600 00	
Sale of printed lecture notes	1,662 69	
Interest	2,868 59	
James Henry Mirrlees Scholarship Fund, more than income (see per contra)	76	
Profit and Loss, expenses more than income (see per contra)	3,216 38	
		223,165 74
BEQUESTS, NEW TRUSTS, ETC.		
George Bucknam Dorr Fund	$49,573 47	
Charles Lewis Flint Library Fund	5,000 00	
" " " Scholarship Fund	5,000 00	
Elisha Thacher Loring " "	5,000 00	
William Barton Rogers Alumni Scholarship Fund,	2,000 00	
" " " " "		
Interest	330 06	
R. E. Rogers Fund, balance sale real estate, Phila.,	990 48	
Sale of 154 Chicago, Burlington & Quincy rights	146 30	
Income Susan H. Swett Fund, not used	182 95	
" James Savage Fund, " "	508 76	
" Richard Perkins Fund, " "	131 40	
" Charles Lewis Flint Fund, " "	177 58	
" Elisha Thacher Loring Fund, " "	157 84	
Interest Joy Scholarship, deposited in Savings Banks	446 13	
		69,644 97
SALE OF SECURITIES UNDER ROGERS MEMORIAL FUND.		
Kansas City, E. & Southern R'y bonds	$7,000 00	
" Lawrence & Southern R'y "	6,000 00	
Cowley, Sumner & Fort Smith R'y "	2,000 00	
Florence, Eldorado & Walnut Valley R'y "	1,000 00	
Quincy & Warsaw R'y "	4,000 00	
Account of Bond Premiums	3,116 25	
Sale of Atchison Scrip	55 45	
" 220 Chicago, Burlington & Quincy Rights	209 00	
		23,380 70
SUNDRIES.		
From State of Massachusetts	$50,000 00	
Subscriptions of 1887	36,000 00	
Income William Barton Rogers Memorial Fund, credited to Advance Bond Premiums	1,598 53	
Students' Notes Receivable	2,248 00	
Sale 1004 Walnut Street, Philadelphia	3,490 48	
		93,337 01
		$442,098 54

with THE MASS. INSTITUTE OF TECHNOLOGY.

FOR THE YEAR ENDING SEPTEMBER 30, 1890.

Cr.

Paid for Lowell Courses	$2,500 00	
" " Charles Kastner's salary	2,500 00	
Expense Lowell School of Design	1,089 04	
		$6,089 04

EXPENSES.

Salaries, per Table. (Page 12)	$146,409 41	
Scholarships	2,968 75	
" Susan H. Swett	125 00	
Repairs, per Table. (Page 13)	9,740 43	
General Expense, per Table. (Page 13)	14,384 63	
Fuel	7,544 46	
Water	1,111 77	
Gas	1,906 06	
Printing and Advertising	1,721 96	
" Lecture Notes	1,861 38	
" Annual Catalogue	1,595 23	
Rent paid Boston & Albany Railway Company	180 00	
Laboratory Supplies, per Table. (Page 12)	24,705 32	
Society of Arts	17 87	
Interest, per Table. (Page 12)	8,893 47	
		223,165 74

INVESTMENTS, ETC.

Securities for Dorr Fund	$48,928 88	
Atchison, Topeka & Santa Fé Guarantee Note	50,000 00	
Joy Scholarship Fund	646 13	
Mirrlees Scholarship Fund, expenses over income,	76	
		99,575 77

PURCHASE SECURITIES FOR W. B. ROGERS MEMORIAL FUND.

$16,000 Atchison, Topeka & Santa Fé 4s	$13,684 80	
$8,400 Atchison, Topeka & Santa Fé Incomes	5,376 00	
Atchison Scrip	55 45	
		19,116 25

SUNDRIES.

Students, on account deposits	$100 00	
On account of New Boiler, No. 2	607 59	
Building on Trinity Place	67,289 34	
Equipment Engineering Building	16,555 24	
Gain on sale of real estate, Philadelphia, carried to R. E. Rogers Fund	990 48	
Profit and Loss, per contra	3,216 38	
		88,759 03
Cash Balance, Sept. 30, 1890		5,392 71
		$442,098 54

The following account exhibits the property held by the Institute, as per Treasurer's books, Sept. 30, 1890: —

INVESTMENT OF THE W. B. ROGERS MEMORIAL FUND.

Cin., Ind., St. Louis & Chicago R. R. 6s	$4,000 00	
Omaha & Southwestern R. R. 8s	7,000 00	
Mo. Valley, Blair R'y & Bridge Co. 6s	20,000 00	
Saginaw & Western R. R. 6s	50,000 00	
Kansas City, Clinton & Springfield R. R. 5s	16,000 00	
Republican Valley R. R. 6s	5,400 00	
Kansas City, Memphis & Birmingham R. R. 5s	1,905 00	
Grand Rapids, Newaygo & L. Shore R. R. 8s	34,000 00	
Burlington & Mo. River R. R. 4s	25,787 50	
Ottawa, Oswego & Fox River R. R. 8s	2,000 00	
Lincoln & Northwestern R. R. 7s	1,000 00	
Atchison & Nebraska R. R. 7s	1,000 00	
Kansas City Belt R. R. 6s	25,000 00	
Atchison, Topeka & Santa Fé R. R. 4s	13,684 80	
" " " " Incomes	5,376 00	
Bonds	$212,153 30	
Advances to Premium Account	16,381 36	
220 shares Chicago, Burlington & Q. R. R. Stock	22,000 00	
		$250,534 66

INVESTMENT OF JOY SCHOLARSHIP FUND.

Mass. Hospital Life Insurance Co.	$5,000 00	
Deposits in Savings Banks	3,159 63	
		8,159 63

INVESTMENT OF SWETT SCHOLARSHIP FUND.

Mass. Hospital Life Insurance Co.	10,000 00

INVESTMENT OF OTHER TRUSTS.

Atchison, Topeka & Santa Fé R. R. 4s	$1,687 50	
" " " " 6s	50,000 00	
" " " " Incomes	301 88	
Quincy & Palmyra R. R. 8s	25,000 00	
Chicago, Burlington & Quincy R. R. 4s	5,100 00	
" " " " 7s	7,000 00	
Burlington & Mo. Ry. Land Grant 7s	15,000 00	
" " Nebraska 6s	19,000 00	
International & G. Northern R. R. 6s	1,000 00	
Milwaukee & St. Paul R. R. $7\frac{3}{10}$s	3,000 00	
Cincinnati & Indiana R. R. 7s	2,000 00	
Union Pacific R. R. 6s	1,000 00	
Chicago, B. & Northern R. R. 5s	2,000 00	
Bonds	$132,089 38	
Advances to Premium Account	6,949 45	
		139,038 83
Amount carried up		$407,733 12

Amount brought up		$407,733 12

STOCKS.

54 shares Chicago, Burlington & Quincy R. R.	$15,400 00	
40 " New York & Harlem R. R.	2,000 00	
20 " Pittsburg, Ft. Wayne & C. R. R.	2,000 00	
82 " Morris & Essex R. R.	4,100 00	
55 " Old Boston National Bank	5,510 50	
12 " Cocheco Manufacturing Co.	6,000 00	
35 " Everett Mills	3,150 00	
50 " Hamilton Woollen Co.	5,000 00	
27 " Essex Co.	4,050 00	
15 " Consolidated Gas Co., New York	1,447 50	
75 " Pennsylvania Coal Co.	3,750 00	
		2,408 00

REAL ESTATE.

Rogers Building	$315,726 88	
New Building of 1883	190,492 44	
Mechanic Arts Building	52,416 49	
Gymnasium Building	3,713 36	
Land on Garrison Street	50,840 00	
Land on Trinity Place	76,315 69	
Building on Trinity Place	106,616 87	
		796,121 73
Equipment Engineering Building	$16,555 24	
" Mechanic Arts Building	20,628 56	
		37,183 80

SUNDRIES.

Notes Receivable	$1,500 00	
Students' Notes	3,657 00	
Lowell School of Design	216 45	
Paid on account New Boiler	607 59	
Cash balance Sept. 30, 1890	5,392 71	
		11,373 75
		$1,304,820 40

The foregoing Property represents the following Funds and Balances, and is answerable for the same.

The Income of the following named is used for the general purposes of the Institute: —

Wm. Barton Rogers Memorial Fund	$250,225 00	
Albion K. P. Welch Fund	5,000 00	
McGregor "	2,500 00	
Nathaniel C. Nash "	10,000 00	
Robert E. Rogers "	7,680 77	
Richard Perkins "	50,000 00	
Stanton Blake "	5,000 00	
Sidney Bartlett "	10,000 00	
Geo. Bucknam Dorr "	49,573 47	
General Institute "	36,028 00	
		$426,007 24

The Income of the following is used towards paying salaries: —

Jas. Hayward, for Professorship of Engineering,	$18,800 00	
Nathaniel Thayer, for " " Physics	25,000 00	
Wm. P. Mason, " " " Geology	18,800 00	
Henry B. Rogers " General Salaries	25,000 00	
		87,600 00

SCHOLARSHIP TRUSTS.

Mrs. Susan H. Swett Fund	$10,182 95	
Joy "	8,159 63	
Thomas Sherwin "	5,000 00	
James Savage "	11,253 40	
James H. Mirrlees "	2,623 00	
Wm. Barton Rogers Alumni Fund	7,884 02	
Richard Perkins Fund	51,876 97	
Farnsworth "	5,000 00	
Charles Lewis Flint Fund	5,177 58	
Elisha Thacher Loring Fund	5,157 84	
		112,315 39
Charles Lewis Flint Fund for Library		5,000 00

MISCELLANEOUS.

Notes Payable	$20,000 00	
Students' Deposits	450 00	
Subscription of 1887	123,500 00	
M. I. T. Stock Account	529,947 77	
		673,897 77
		$1,304,820 40

COMPARATIVE STATEMENT OF FUNDS, ETC.

	Sept. 30, 1889.	Sept. 30, 1890.
Trusts for general purposes	$375,443 29	$426,007 24
" " Salaries	87,000 00	87,000 00
" " Scholarships	98,181 43	112,315 89
" " Library		5,000 00
Income Joy Fund	200 00	
Notes Payable	20,000 00	20,000 00
Students' Deposits	550 00	450 00
Subscriptions of 1887	87,500 00	123,500 00
M. I. T. Stock Account	483,164 15	520,047 77
Advances to Bond Premiums	9,146 25	
	$1,161,785 12	$1,304,820 40
Increase	143,035 28	
Consisting of: —		
Geo. B. Dorr Fund (new)	49,573 47	
C. L. Flint Scholarship " "	5,000 00	
E. T. Loring " " "	5,000 00	
C. L. Flint Library " "	5,000 00	
Increase of Robert E. Rogers Fund	990 48	
" " Wm. Barton Rogers Scholarship Fund	2,330 06	
Increase of Scholarship Funds	1,803 90	
Subscriptions of 1887 paid	36,000 00	
Increase of Stock Account	46,783 62	
		152,481 53
Students' Deposits less	$100 00	
Income Joy Fund deposited	200 00	
Advances to Bond Premiums	9,146 25	
		9,446 25
		$143,035 28

INCOME FROM GENERAL INVESTMENTS, AND APPLICATION THEREOF.

Applied to Salaries	$4,147	86	
" " Scholarships	2,916	49	
" " Library	177	58	
" " General Purposes	8,276	66	
" " Increase of Funds	1,305	64	
	$16,824	23	

From Dividends, Old Boston National Bank	$220	00	
" State Tax returned, Old Boston National Bank	85	69	
" Railroad Bonds	4,993	88	
" Essex Co. Dividend	162	00	
" Cocheco Co. Dividend	240	00	
" Hamilton Woolen Co. Dividend	300	00	
" Chicago, B. & Q. Ry. "	645	00	
" Consolidated Gas Co. "	37	50	
" New York & Harlem Ry. "	80	00	
" Morris & Essex Ry. "	143	50	
" Pennsylvania Coal Co. "	300	00	
" Pittsburg & Fort Wayne Ry. "	35	00	
" Dorr Estate	1,291	19	
" Rent, 1004 Walnut St., Philadelphia	93	18	
" Interest, Atchison Note	75	00	
" Wm. B. Rogers Memorial Fund	228	82	
" Interest on Funds not in Bonds and Stocks @ $4\frac{736}{1000}$ %, the rate on earnings invested	7,893	47	
	$16,824	23	

INCOME FROM WILLIAM BARTON ROGERS MEMORIAL FUND, AND APPLICATION THEREOF.

Paid Massachusetts Institute of Technology 5%		From Railroad Bonds	$13,293 60
on Amount of Fund ($250,225) . . .	$12,511 25	Dividend, 220 shares, Chicago, Burlington &	
Transferred to General Income for Amount over		Quincy R. R. Co.	1,045 00
invested $4,057.83 @ $\frac{539}{1000}$ rate earned by			
this Fund	228 82		
Credited to Advances Bond Premiums . .	1,598 53		
	$14,338 60		$14,338 60

DETAILS SOME ITEMS IN TREASURER'S CASH ACCOUNT.

Rents.

Huntington Hall, for Lowell Lectures	$2,500 00	
Lowell School of Design	1,400 00	
Chauncy Hall School, for Gymnasium	300 00	
State Board of Health, for use of Laboratories	1,062 50	
Use of Lecture Rooms and Gymnasium	80 00	
		$5,342 50

Department Supplies.

Chemical Department	$6,439 83	
Physical "	4,702 28	
Mining "	1,774 54	
Mechanical "	2,951 46	
Applied Mechanics "	461 13	
Civil Engineering "	1,460 19	
Biological "	1,506 63	
Geological "	207 33	
Architectural "	1,632 67	
Drawing "	22 82	
Mathematical "	73 69	
English "	1,118 71	
Workshops "	1,252 06	
Periodicals	1,101 98	
		$24,705 32

Salaries.

Instruction	$118,952 47	
Administration	13,286 19	
Labor	14,170 75	
		$146,409 41

Interest Paid.

Augustus Lowell, Trustee	$1,000 00	
On $166,704.67 not invested in Stocks or Bonds	7,893 47	
		$8,893 47

Repairs.

Department Improvements: —			
Mining Department	$952 96		
Chemical "	705 79		
Physical "	567 52		
Drawing "	418 34		
Architectural "	387 28		
English "	153 25		
Biological "	138 95		
		$3,324 09	
Reading, Lecture Rooms, and Secretary's Office, alterations		349 10	
Lunch Room		815 51	
Pointing Rogers Building		513 19	
" Building of 1883		324 19	
Painting, etc., Halls and Rooms, Rogers Building,		1,100 48	
Concreting Dynamo Room		230 00	
Gymnasium		291 17	
Workshops		142 61	
Sundries		2,650 09	
			$9,740 43

General Expenses.

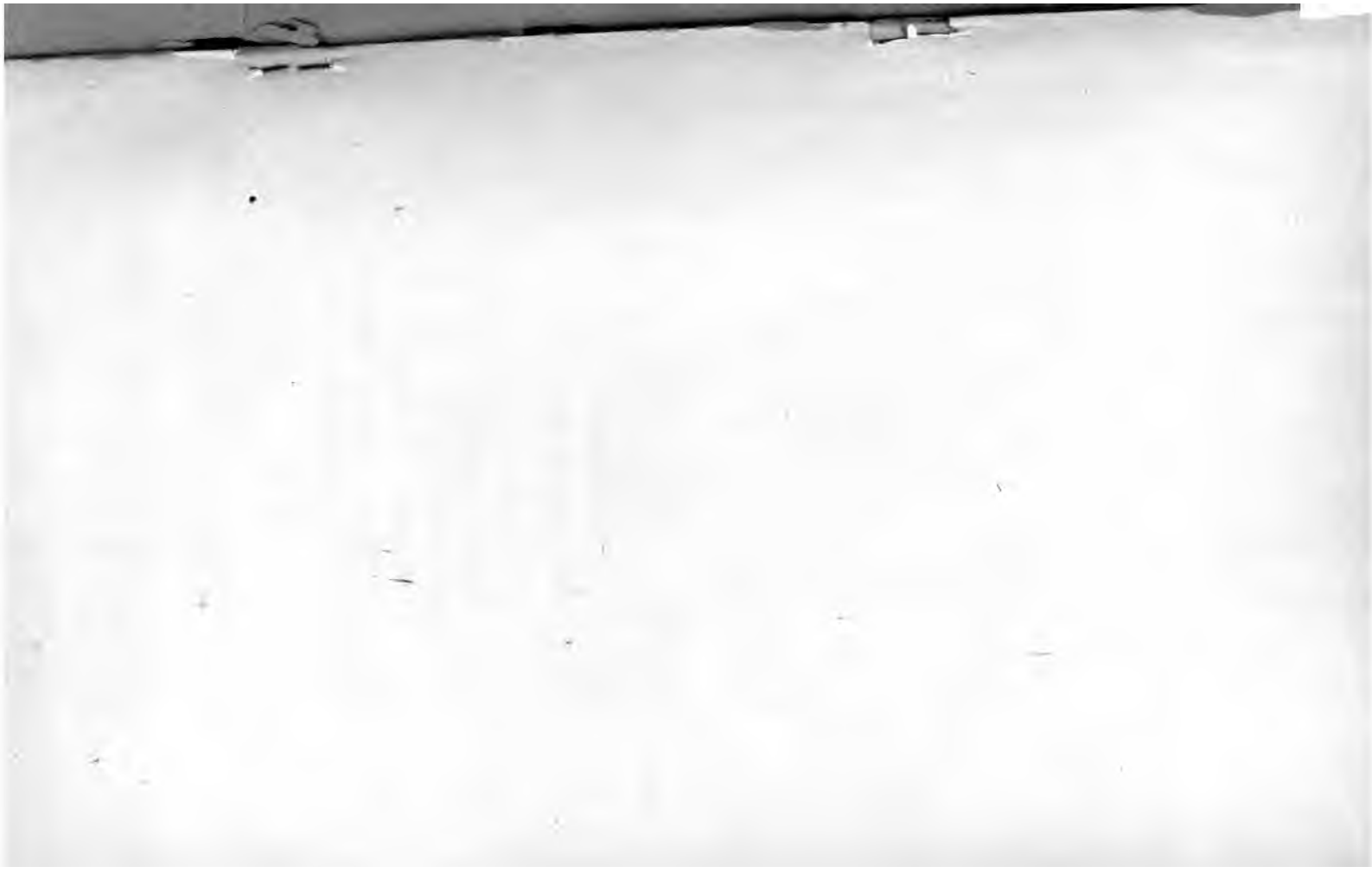
Furniture: —			
Civil and Mechanical Engineering Department, Trinity Place, fitting the same		$1,509 78	
Drawing Department, refitting		737 50	
Lecture Room, New Building of 1883		158 60	
Architectural Department, Reading Room, etc.,		367 88	
			$2,773 76
Electric Lighting: —			
Biological Department	$130 00		
Architectural "	115 00		
Lamps, extending electric service, etc.	423 01		
			668 01
Watchman's Clocks, Rogers, New, and Engineering Buildings, Eco Magneto Clock Co.			530 96
Insurance Premiums			1,343 69
Engine Room Supplies: —			
Cotton Waste	$43 40		
Covering Steam Pipes	174 11		
Reducing Valves	92 25		
Oil	186 28		
Amount carried forward	$496 04		

Amount brought forward	$496 04	
Oil Cabinet	36 00	
Damper Regulators	259 50	
Small Engine in exchange, setting, etc.	369 79	
Fan Engine	69 02	
		$1,230 35
Machinery, Mining Department		440 79
Postage and Stationery		1,155 64
Fire Sprinklers		313 27
" Hose		299 36
" Escapes		188 12
Lunch Room: —		
Steam and Gas Cooking Apparatus, Kitchen and Dining-Room Furniture		399 24
Linen Chair Covers, Huntington Hall		209 00
Window Shades: —		
Engineering Building	$432 50	
Other Buildings	132 73	
		565 23
Diplomas, Commissions, and Expense of Drills		413 40
Entrance Examinations		456 59
Library Supplies		72 93
Office Supplies		346 13
Union Safe Deposit Vaults, rent		50 00
Legal Fees, Dorr Estate		100 00
Boston Electric Time Co.		31 50
Telephone, Rent of		51 81
Express Charges		349 54
Gymnasium, Stove, etc.		50 00
Mats, Waste Baskets, etc.		67 56
Paints, Varnish, etc.		321 14
Washing		280 16
Ice		237 47
Janitor's Supplies: —		
Brushes, Pails, Sponges, Soap, etc.		392 37
Grounds, Improving Lawns, etc.		163 25
Towels, etc.		59 39
Window Glass		45 40
Hardware (petty)		68 79
Moving Effects to Engineering Building		205 51
Petty Supplies, " "		197 81
Ventilation		59 40
Drawings for publication		26 00
Sundries		221 06
		$14,384 63

BOSTON, December 3, 1890.

An examination of the accounts of the Treasurer of the Massachusetts Institute of Technology for the year ending Sept. 30, 1890, has been made, and they are found to be correctly cast, and with proper vouchers. The Ledger Balances agree with the Trial Balance. We have verified the evidences of personal property held by the Institute.

FREDERIC W. LINCOLN,
CHARLES C. JACKSON,
Auditing Committee.



43

ANNUAL REPORT

OF THE

PRESIDENT AND TREASURER

OF THE

MASSACHUSETTS

INSTITUTE OF TECHNOLOGY,

DEC. 9, 1891.

BOSTON:
ALFRED MUDGE & SON, PRINTERS,
No. 24 FRANKLIN STREET.
1892.

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ANNUAL REPORT

OF THE

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INSTITUTE OF TECHNOLOGY,

DEC. 9, 1891.

BOSTON:
ALFRED MUDGE & SON, PRINTERS,
No. 24 Franklin Street.
1892.

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Secretary.
FRANCIS H. WILLIAMS.

Treasurer.
GEORGE WIGGLESWORTH.

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JOHN D. RUNKLE.
ALEXANDER H. RICE.
M. DENMAN ROSS.
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HENRY SALTONSTALL.
HENRY L. PIERCE.
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JACOB A. DRESSER.
THOMAS L. LIVERMORE.
A. LAWRENCE ROTCH.

On the Part of the Commonwealth.

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HON. WALBRIDGE A. FIELD, *Chief-Justice of the Supreme Court.*
HON. JOHN W. DICKINSON, *Secretary of the Board of Education.*

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GEORGE WIGGLESWORTH. } *Ex Officiis.*

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ALEXANDER S. WHEELER. FRANCIS H. WILLIAMS.
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NATHANIEL THAYER.

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ALEXANDER H. RICE. HOWARD STOCKTON.
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FRANCIS A. WALKER.

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Departments of Mechanical Engineering and Applied Mechanics.

HIRAM F. MILLS. FRANCIS BLAKE.
DESMOND FITZGERALD. JAMES P. TOLMAN.

Departments of Mining and Metallurgy.

THOMAS T. BOUVÉ. HOWARD STOCKTON.
CHARLES FAIRCHILD. THOMAS L. LIVERMORE.

Department of Architecture.

ARTHUR ROTCH. FREDERICK L. AMES.
ELIOT C. CLARKE. THORNTON K. LOTHROP.

Departments of Literature, History, and Political Economy.

ALEXANDER H. RICE. JOHN W. DICKINSON.
HENRY L. PIERCE. FRANCIS A. WATERHOUSE

Department of Modern Languages.

FRANCIS A. WATERHOUSE. NATHANIEL THAYER.
ARTHUR ROTCH.

Department of Mathematics.

HOWARD A. CARSON. CHARLES J. PAINE.
PERCIVAL LOWELL. DESMOND FITZGERALD.

Departments of Chemistry, Physics, and Biology.

SAMUEL CABOT. JAMES M. CRAFTS.
CHARLES C. JACKSON. A. LAWRENCE ROTCH.

Department of Chemical Engineering.

ARTHUR T. LYMAN. SAMUEL CABOT.
HIRAM F. MILLS. CHARLES W. HUBBARD.

Lowell School of Practical Design.

PERCIVAL LOWELL. JOHN D. RUNKLE.
M. DENMAN ROSS. JACOB A. DRESSER.

To the Corporation of the Massachusetts Institute of Technology: —

It is my pleasant duty to report another year of fortunate progress at the Institute of Technology. Things have, on the whole, gone wonderfully well with us. The reputation of the school is steadily extending outwards; the spirit of the school is steadily rising within. Each succeeding year, as our work increases in amount, we have the satisfaction of feeling that it is better done. The increase in our numbers has not been more marked than has been the improvement in the quality of the instruction given at the Institute.

One event to grieve us deeply has occurred since our last annual meeting in the death of our esteemed and beloved colleague, Hon. Samuel C. Cobb. His devotion to the Institute was sincere and earnest. He was one of our most attentive and diligent members throughout his long term of service upon the Corporation; and it pleased him at his death to remember the Institute in the distribution of his worldly estate.

The retirement of Mr. Tappan from the secretaryship of the Corporation, in consequence of delicate health, is regretted by us all. Mr. Tappan has, by many years of faithful service in the offices of Bursar, Secretary and Treasurer, acquired an intimate knowledge of the school, — its history, organization, traditions, methods, — such, perhaps, as is possessed by no other member of the Corporation. Fortunately he remains with us, though reluctantly relinquishing the positions of special responsibility

which he has held so much to the advantage of the Institute.

Of the 102 graduating members of the class of 1891, 17 graduated in civil engineering, 26 in mechanical engineering, 4 in mining engineering, 6 in architecture, 11 in chemistry, 23 in electrical engineering, 3 in biology, 3 in physics; 1 graduated from the department of general studies, 7 in chemical engineering and 1 in geology. All courses of the school, except Course XI., sanitary engineering, which was only instituted in 1889, were thus represented in the award of diplomas. The fourth-year students of the year now current comprise candidates for the degree of the Institute in each of the twelve courses here carried on. At the coming Commencement, Course XI. will present several candidates for the degree.

The new year has witnessed another large increase in the number of students in the school. The total registration, this year, as by the catalogue now in press, amounts to 1,011 against 937 last year, a gain of 74. The following table exhibits the number of the students in the school each year, from the opening of the Institute to the present time: —

Year.	No. of Students.	Year.	No. of Students.
1865–66	72	1879–80	203
1866–67	137	1880–81	253
1867–68	167	1881–82	302
1868–69	172	1882–83	368
1869–70	206	1883–84	443
1870–71	224	1884–85	579
1871–72	261	1885–86	609
1872–73	348	1886–87	637
1873–74	276	1887–88	720
1874–75	248	1888–89	827
1875–76	255	1889–90	909
1876–77	215	1890–91	937
1877–78	194	1891–92	1011
1878–79	188		

STUDENTS BY CLASSES.

The aggregate number of students for 1890–91 is divided among the several classes as follows: —

Graduate students, candidates for advanced degrees		2
Regular students,	Fourth Year	146
" "	Third Year	140
" "	Second Year	155
" "	First Year	263
Special students		305
Total		1,011

This table shows the number of regular students of the fourth year to hold a larger ratio to the total number of students in the school than ever before. The ratio this year is 14.5 per cent against 11.2 last year.

Assigning the special students to classes, according to the predominant studies pursued by them, we reach the following statement of the division of the whole body among the several years: —

Class.	Regular.	Special.	Total.
Graduates of the M. I. T., candidates for advanced degrees	2		2
Fourth Year	146	29	175
Third Year	140	92	232
Second Year	155	129	284
First Year	263	55	318
Total	706	305	1,011

STATISTICS OF EXAMINATIONS.

Of the 1,011 students of the present year, 387 were not connected with the school in 1890–91.

Fifteen had been connected with the Institute at some previous time, and returned to resume their places in the

school; 38 were admitted provisionally, without examination; 9 were admitted by examination to the second year; 37 were admitted on the presentation of diplomas or certificates from other institutions.

Excluding from consideration those who were admitted but have not, in fact, entered the school, 53 in number, the following was the result of the examinations held: —

Admitted clear	87	
" on one condition	87	
" " two conditions	51	
" " three "	32	
" " more than three conditions	8	265
Rejected		53
		318

EXAMINATIONS AT DISTANT POINTS.

In addition to the entrance examinations held in Boston in June and September, 1891, examinations were also conducted, in June, at Chicago, Cincinnati, Montreal, New York, Philadelphia, Pittsburg, Portland, Oreg., San Francisco, St. Louis, St. Paul, and Washington.

RESIDENCE OF STUDENTS.

Thirty-eight States of the Union, besides the District of Columbia and New Mexico, are represented on our list of students. Of the total number of 1,011, including special students, 565 are from Massachusetts, or 55.88 per cent of the whole; 102 are from other New England States; 334 from outside New England, of whom 38 are from foreign countries.

The following table shows the number of students of each specified class from each State or foreign country: —

State.	Candidates for Advanced Degree.	Fourth Year.	Third Year.	Second Year.	First Year.	All Regular Students.	Special Students.	Total.
Alabama	....	..	..	..	1	1	1	2
Arkansas	....	1	..	1	...	2	1	3
California	....	4	1	3	4	12	7	19
Colorado	....	..	1	1	2	4	3	7
Connecticut	....	6	4	3	5	18	12	30
Dist. Columbia	....	..	..	2	1	3	1	4
Florida	....	..	1	1	1	3	...	3
Georgia	....	1	..	..	...	1	1	2
Idaho	....	..	..	.	...	...	1	1
Illinois	....	7	6	5	4	22	10	32
Indiana	....	..	..	..	1	1	2	3
Iowa	....	..	1	1	3	5	5	10
Kansas	....	..	..	..	.	...	2	2
Kentucky	....	1	1	2	3	7	1	8
Louisiana	....	..	..	2	1	3	2	5
Maine	....	2	6	2	11	21	6	27
Maryland	....	2	..	..	3	5	2	7
Massachusetts	2	88	83	89	157	419	146	565
Michigan	....	1	3	..	3	7	6	13
Minnesota	....	1	3	4	2	10	3	13
Missouri	....	1	2	1	2	6	6	12
Nebraska	....	..	..	..	1	1	...	1
Nevada	....	..	..	1	2	3	...	3
N. Hampshire	....	1	5	5	5	16	8	24
New Jersey	....	3	3	1	3	10	6	16
New Mexico	....	..	..	..	1	1	...	1
New York	....	3	4	7	12	26	14	40
No. Carolina	....	1	..	..	...	1	...	1
Ohio	....	6	5	3	6	20	13	33
Oregon	....	..	..	..	..	...	1	1
Pennsylvania	....	4	3	6	7	20	6	26
Rhode Island	....	2	4	4	7	17	9	26
So. Carolina	....	..	..	1	...	1	3	4
Tennessee	....	...	...	...	...	...	4	4
Texas	....	...	...	...	...	...	2	2
Vermont	....	...	...	1	2	3	2	5
Virginia	....	2	1	...	..	3	3	6
Washington	....	1	...	...	1	2	1	3
West Virginia	....	...	1	...	...	1	1	2
Wisconsin	....	2	...	1	2	5	2	7
Foreign Countries.								
Brazil	....	1	...	...	3	4	...	4
Bulgaria	....	...	1	...	...	1	...	1
Cent'l America	....	...	...	1	...	1	...	1
Colombia	....	...	...	...	1	1	1	2
England	....	...	...	1	...	1	...	1
France	....	...	...	...	...	...	1	1
Hawaiian Isl'ds	....	...	...	2	...	2	2	4
Holland	....	...	...	...	2	2	...	2
Japan	....	...	1	1	...	2	1	3
Mexico	....	...	...	...	...	...	1	1
N. Brunswick	....	1	...	...	1	2	...	2
New So. Wales	....	...	...	...	...	...	1	1
Nova Scotia	....	...	...	...	...	...	1	1
Peru	....	...	...	...	...	...	1	1
Porto Rico	....	...	...	...	...	...	1	1
Prov. Ontario	....	...	...	1	1	2	...	2
Prov. Quebec	....	...	...	2	1	3	1	4
Scotland	....	1	...	...	...	1	1	2
Trinidad	....	1	...	...	...	1	...	1
Turkey	....	2	...	...	...	2	...	2
Venezuela	....	...	...	...	1	1	...	1
Total	2	146	140	155	263	706	305	1011

When it is considered how many scientific and technical schools have been founded during the past three or four years, and how many colleges and universities have established scientific and technical departments during the same period, it is gratifying to note the firmness with which this Massachusetts school has maintained its hold upon its wide geographical constituency. For this we have largely to thank our alumni, whose high standard of professional conduct, not less, even, than their scientific attainments or their devoted loyalty to their *alma mater*,

has done much to promote the reputation of the Institute in distant States.

A table showing the number of students in each year from and including 1885, coming from each state or territory and from each foreign country, may not be without interest and instruction: —

States.	1885.	1886.	1887.	1888.	1889.	1890.	1891.
Alabama	2	...	...	...	1	...	2
Arkansas	...	2	3	2	2	3	3
California	5	8	9	13	10	14	19
Colorado	1	...	2	2	6	4	7
Connecticut	16	16	29	28	36	31	30
Delaware	1	1	...	...	...	1	...
Dist. of Columbia,	4	4	4	9	9	7	4
Florida	...	...	...	...	2	3	3
Georgia	2	3	2	1	1	2	2
Idaho Territory	...	...	...	...	...	...	1
Illinois	20	19	29	37	33	34	32
Indiana	1	2	...	1	3	6	3
Iowa	6	6	3	6	4	9	10
Kansas	2	2	...	...	...	2	2
Kentucky	5	4	2	3	4	4	8
Louisiana	1	...	...	2	4	8	5
Maine	22	20	24	26	30	29	27
Maryland	1	2	2	4	4	7	7
Massachusetts	387	402	429	494	533	517	565
Michigan	3	5	10	12	13	16	13
Minnesota	5	4	6	8	10	12	13
Mississippi	1	...	...	...	...	...	...
Missouri	2	1	5	7	8	8	12
Montana	...	...	...	...	...	1	...
Nebraska	3	2	4	2	1	1	1
Nevada	1	1	...	...	...	1	3
New Hampshire	22	26	19	24	21	23	24
New Jersey	5	7	11	8	13	11	16
New Mexico	...	...	...	2	...	...	1
New York	17	24	35	31	25	40	40
North Carolina	1	...	...	1	2	1	1
Ohio	18	21	21	23	35	33	33
Oregon	1	1	...	1	2	1	1
Pennsylvania	15	13	18	18	23	22	26
Rhode Island	12	17	19	22	22	21	26
South Carolina	2	1	1	...	1	2	4
South Dakota	...	1	1	1	1	...	...
Tennessee	2	1	2	3	5	3	4
Texas	...	...	1	2	...	1	2
Vermont	6	5	7	5	4	4	5
Virginia	5	3	5	4	6	5	6
Washington	...	...	1	...	2	2	3
West Virginia	...	1	...	...	2	2	2
Wisconsin	1	3	5	7	9	10	7
Wyoming Terr.	...	...	...	1	...	...	...
Foreign Count's.							
Argentine Rep.	...	...	...	...	...	2	...
Belgium	...	1	...	...	...	...	...
Brazil	...	...	1	2	2	2	4
Bulgaria	...	...	...	...	1	1	1
Central America	...	...	...	...	...	...	1
Chili	1	...	...	...	...	...	...
Colombia	...	.	...	...	1	...	2
Cuba	1	..	...	...	...	...	...
England	...	...	...	...	...	2	1
France	...	...	...	...	1	1	1
Greece	...	...	...	1	...	...	...
Guatemala	...	...	1	1	1	...	...
Guiana	...	...	...	...	...	...	...
Hawaiian Islands,	...	...	...	1	1	4	4
Holland	...	...	...	...	...	...	2
India	...	...	...	...	...	...	...
Ireland	...	...	1	1	1	1	...
Japan	1	1	1	...	1	4	3
Mexico	...	..	...	...	1	1	1
New Brunswick	3	1	...	1	1	1	2
New South Wales,	...	...	...	...	...	...	1
Nova Scotia	...	...	...	...	2	2	1
Peru	...	2	1	2	1	3	1
Porto Rico	...	...	1	2	2	2	1
Province Ontario	...	...	1	2	1	1	2
Province Quebec	3	3	2	1	1	4	4
Scotland	2	...	...	1	1	3	2
Trinidad	...	...	1	1	1	1	1
Turkey	...	...	1	1	2	1	2
Venezuela	...	...	...	...	...	...	1
Total	609	637	720	827	909	937	1011

RESIDENCE OF MASSACHUSETTS STUDENTS.

It has been said that 55.88 per cent of our students are from Massachusetts. All the counties of the State, except the small counties of Dukes and Nantucket, send students

to the Institute. One hundred and ten cities and towns are borne on the lists, four more than last year. The first column of the following table shows the number of cities and towns in each county sending pupils to the Institute; the second column gives the aggregate number from each county. It appears that Suffolk sends us 190 pupils; Middlesex comes next, with 169; Norfolk third, with 67; Essex fourth, with 58. Last year Middlesex County led the list.

County.	No. of Towns.	No. of Students.	County.	No. of Towns.	No. of Students.
Barnstable	2	3	Hampshire	1	1
Berkshire	2	3	Middlesex	30	169
Bristol	5	13	Norfolk	20	67
Essex	16	58	Plymouth	13	28
Franklin	1	2	Suffolk	4	190
Hampden	4	12	Worcester	12	19
	30	91	Total	110	565

The following is a list of the towns, thirty-three in number, which send four or more scholars to the Institute: —

Boston	176	Framingham	8	Belmont	4
Newton	28	Lowell	8	Dedham	4
Cambridge	20	Springfield	8	Fall River	4
Brookline	17	Wellesley	8	Fitchburg	4
Somerville	14	Salem	7	Hingham	4
Waltham	14	Arlington	6	Kingston	4
Lynn	13	Lawrence	6	Needham	4
Malden	12	Medford	6	Reading	4
Chelsea	11	Melrose	5	Rockland	4
Newburyport	10	Woburn	5	Taunton	4
Hyde Park	9	Abington	4	Watertown	4

PROPORTION OF OLD AND OF NEW STUDENTS.

The following table exhibits, for each year since 1883, the distribution of the total number of students among two classes: first, those students whose names are found

upon the catalogue of the year preceding; and secondly, those students whose names appear as new names upon the catalogue of the year to which the statement relates: —

Year.	(1) Total No. of Students.	(2) No. of Students in the Catalogue of the previous year who remain in the Institute.	(3) No. of New Students entering before issue of Catalogue.	(4) Of those in column (3) the following number are regular first-year Students.	(5) No. of New Students, not of the regular first-year class.
1883–84	443	231	212	140	72
1884–85	579	311	268	186	82
1885–86	609	369	240	177	63
1886–87	637	379	258	190	68
1887–88	720	396	324	229	95
1888–89	827	465	362	245	117
1889–90	909	557	352	255	97
1890–91	937	572	365	234	131
1891–92	1,011	624	387	258 *	129

It appears from the foregoing that the number of students remaining over has been increased by 52, while the number registered for the first time is larger by 22, making the total gain, as previously stated, 74.

AGES OF STUDENTS ON ENTRANCE.

The next table exhibits the ages of our students upon entrance. The regular students of the first-year class number 263. From these we should except 12 cases of students of unusual ages. These deductions leave 251 as the number of students whose ages have been made the subject of computation.

The results appear in the following table, in comparison with the corresponding results for 1890–91: —

* In addition, 5 students are repeating the first year.

Period of Life.	1890–91.		1891–92.	
	Half-Year Groups.	Yearly Groups.	Half-Year Groups.	Yearly Groups.
16 to 16½ years	1	..	..	..
16½ to 17 years	10	11	4	4
17 to 17½ years	11	..	26	..
17½ to 18 years	32	43	39	65
18 to 18½ years	48	..	41	..
18½ to 19 years	53	101	50	91
19 to 19½ years	38	.	35	..
19½ to 20 years	24	62	21	56
20 to 20½ years	10	..	18	..
20½ to 21 years	9	19	8	26
21 to 22 years	10	10	9	9
	246	246	251	251

From the foregoing tables it appears that the average age of the 251 students taken for this comparison, the present year, is 18 years and 9 months.

In this connection it may be interesting to note the ages at graduation of the class leaving us in June. The 102 members of the class were distributed among the several periods of life, as follows:—

Under 20	1	Between 22 and 23	23
Between 20 and 20½	3	" 23 and 24	14
" 20½ and 21	11	24 and over	15
" 21 and 21½	13		—
" 21½ and 22	22		102

PROPORTION OF REGULAR AND OF SPECIAL STUDENTS.

The following table exhibits both the absolute number of regular and of special students, as by the catalogue of each successive year since 1882, and the proportion existing between these two classes:—

Year.	No. of Regular Students.	No. of Special Students.	Total No. of Students.	Percentage.	
				Regular.	Special.
1882–83	219	149	368	60	40
1883–84	272	171	443	61	39
1884–85	368	211	579	64	36
1885–86	415	194	609	68	32
1886–87	442	195	637	69	31
1887–88	520	200	720	72	28
1888–89	590	237	827	71	29
1889–90	652	257	909	72	28
1890–91	658	279	937	70	30
1891–92	706	305	1,011	70	30

WOMEN AS STUDENTS IN THE INSTITUTE.

The number of women pursuing courses with us is 26. Of this number, 5 are graduates of colleges. Of the total number, 4 are regular students of the fourth year; 1 of the third year; 4 of the second year. Seventeen are special students. Of the 9 regular students of the upper classes, 1 takes Course IV., architecture; 1 Course V., chemistry; 4 Course VII., natural history; 2 Course VIII., physics; 1 Course XII., geology. Of the special students, 3 devote themselves to architecture, 4 to chemistry, 4 to physics; 2 chiefly to biology and allied subjects; and 2 to political science. Two are reported as special students on account of their deficiencies in French, who are, in all other particulars, taking the full course in the first year.

GRADUATES OF OTHER COLLEGES.

Fifty graduates of institutions conferring degrees are included in our list of students for the present year. Of these, 8 are our own graduates, of whom 2 are pursuing studies as candidates for advanced degrees. Forty-two are graduates of other institutions pursuing courses of study with us, either as regular or as special students. Of

these, 10 are graduates of Harvard University, 5 of Amherst College, 2 each of Brown University, St. John's College, Smith College, and Allegheny College, while one comes from each of the following institutions: Yale University, Brown University, University of Michigan, Middlebury College, Wellesley College, University of Alabama, Central University, Cornell University, Vanderbilt University, National Deaf Mute College, Ogden College, University of the South, Bowdoin College, University of Virginia, Kansas State Agricultural College, Robert College, Trinity College, University of the City of New York, and State University of Iowa.

Of the 48, not candidates for advanced degrees here, 12 are regular students of the fourth year, — 2 in civil engineering, 1 in mechanical engineering, 1 in architecture, 8 in electrical engineering; 6 are regular students in the third year, — 3 in civil engineering, 1 in mining engineering, 2 in electrical engineering; 2 are regular students in the second year, — 1 in civil engineering, and 1 in architecture; 2 are regular students in the first year; the remaining 26 are special students.

The increase in the number of our own graduates returning, either to take full additional courses or to perfect themselves in some special department of knowledge, is gratifying. It is much to be desired that this number should increase until it comes to include no inconsiderable part of the graduates of the preceding year. Mr. J. A. Meyer, Jr., of the last class in architecture, and Mr. Clement March, of the last class in civil engineering, have returned as candidates for higher degrees. Messrs. H. A. Fiske, and H. C. Forbes, of the last class in chemical engineering, and Mr. F. E. Norton, of the last class in mechanical engineering, have returned to take an additional year of study, as candidates for the bachelor's degree in electrical engineering. Miss Maltby, of 1890, now teaching physics at Wellesley College, is taking

advanced studies in physics with Professors Cross and Holman. Mr. E. H. Brownell, of 1890, has returned to take advanced studies in civil engineering. Mr. H. B. Roberts, of 1890, is still continuing his studies here.

THE COURSES OF INSTRUCTION.

The following table presents the number of students in each of the regular courses. It will be seen that this statement relates to the second, third, and fourth years only, choice of courses being made at the end of the first year: —

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Electrical Engineering.	Biology.	Physics.	General Course.	Chemical Engineering.	Sanitary Engineering.	Geology.	Total.
4th Year Class . .	27	30	6	15	6	38	6	1	7	4	5	1	146
3d " " . .	29	31	7	6	7	42	1	. .	8	7	. .	2	140
2d " " . .	25	43	4	12	10	28	4	4	4	17	4	. .	155
Total	81	104	17	33	23	108	11	5	19	28	9	3	441

The following table shows the figures of the total line in the foregoing table, in comparison with the corresponding figures for the seven next preceding years: —

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Electrical Engineering.	Biology.	Physics.	General Course.	Chemical Engineering.	Sanitary Engineering.	Geology.	Total.
1884	29	54	28	9	20	30	1	1	3	. .	. .	. .	175
1885	44	74	26	10	23	41	4	1	5	. .	. .	. .	228
1886	45	75	19	13	24	52	4	2	8	. .	. .	. .	242
1887	50	89	16	18	23	61	5	6	14	. .	. .	. .	282
1888	71	100	12	21	28	74	4	5	12	11	. .	. .	338
1889	79	99	14	30	29	91	9	5	12	14	6	. .	388
1890	79	95	18	27	27	105	11	4	13	18	7	3	407
1891	81	104	17	33	23	108	11	5	19	28	9	3	441

The following table exhibits the number of persons who have graduated within each of the several courses, at each succeeding year since the first diplomas were conferred: —

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering.	Architecture.	Chemistry.	Metallurgy.	Electrical Engineering.	Natural History or Biology.	Physics.	General Course.	Chemical Engineering.	Geology.	Total.
1868	6	1	6	..	..	..	..	..	..	1	..	..	14
1869	2	2	..	..	1	..	..	..	..	..	..	..	5
1870	4	2	2	..	1	..	..	..	..	1	..	..	10
1871	8	2	5	..	2	..	..	..	..	..	..	..	17
1872	3	1	5	..	3	..	..	..	..	..	..	..	12
1873	12	2	3	1	7	..	..	..	..	1	..	..	26
1874	10	4	1	1	..	..	..	..	..	2	..	..	18
1875	10	6	6	1	1	..	..	..	1	2	..	..	27
1876	12	9	7	..	5	1	..	2	3	4	..	..	43
1877	12	6	8	4	2	..	..	..	..	..	..	..	32
1878	8	2	2	3	3	.	..	..	..	1	..	..	19
1879	6	8	3	1	3	..	..	1	1	..	..	..	23
1880	3	..	3	..	1	..	..	..	.	1	..	..	8
1881	3	5	6	3	8	..	..	1	..	2	..	..	28
1882	2	5	5	3	6	..	..	1	1	1	..	..	24
1883	3	7	5	1	3	..	..	..	..	..	..	..	19
1884	5	6	13	..	12	..	..	..	..	..	..	..	36
1885	4	6	8	2	4	..	2	..	..	1	..	..	27
1886	9	23	7	1	7	..	10	1	.	1	..	..	59
1887	10	17	8	1	9	..	8	1	1	3	..	..	58
1888	11	25	4	5	10	..	17	3	1	1	..	..	77
1889	15	23	5	3	8	..	17	1	1	2	..	..	75
1890	25	27	3	5	13	..	18	3	2	6	..	..	102
1891	17	26	4	6	11	..	23	3	3	1	7	1	102
Total,	200	215	119	41	120	1	95	17	14	31	7	1	861
Deduct names counted twice													2
Net total													859

Our special students, of course, cannot be classified systematically; but the following table exhibits the number of such students pursuing each particular branch of study: —

NUMBER OF SPECIAL STUDENTS ATTENDING EXERCISES IN THE FOLLOWING DEPARTMENTS OF STUDY OR PRACTICE.

Acoustics	16	Heating and Ventilation	49
Applied Mechanics	63	History	65
Architecture	74	Hydraulics	12
Biology	8	Industrial Chemistry	7
Business Law	42	Italian	3
Chemistry	87	Mathematics	165
Civil Engineering	7	Mechanics	48
Climatology	1	Metallurgy	20
Descriptive Geometry	108	Military Drill	17
Design	44	Mining Engineering	2
Drawing	81	Organic Chemistry	10
Dynamics of Machines	5	Physics	135
Dynamo Testing	4	Physiology	1
Electrical Engineering	21	Political Economy	30
Elementary French	50	Political Science	7
English	98	Railroad Engineering	12
Engineering Laboratory	4	Shopwork	95
Freehand Drawing	50	Steam Engineering	5
French	37	Surveying	29
Geodesy	2	Thermodynamics	30
Geology	36	Zoölogy	5
German	100		

It may be of interest to note the number of students, either regular or special, pursuing certain leading branches of study, in each of the four years, which are as follows: —

Studies.	First Year.	Second Year.	Third Year.	Fourth Year.	Total.
Mathematics	320	216	158	44	738
Chemistry	321	65	37	26	449
English	296	197	123	61	677
French	213	87	40	24	364
Physics	...	244	178	57	479
German	66	171	127	13	377
Shop-work	21	133	49	44	247

FIVE-YEAR COURSES.

I have given the distribution of the aggregate body of students among the four classes recognized in the catalogue of the school. As a matter of fact, however, this classification has to be somewhat qualified, with reference to the existence of a class of students who are taking five-year courses in the Institute.

In the catalogue of 1878–9, it was stated that "students who find it advantageous to take fewer studies in any one year than are prescribed, may continue in the school a fifth year, to make up the studies required for a degree." This statement, or its equivalent, was repeated in each successive catalogue until that of 1885–6, in which the scheme received a further expansion through the important statement that students duly enrolling themselves to take their courses in five years, would be regarded, not as special, but as regular students. Concurrently with this issue of the catalogue, a circular was distributed to the students, and to their parents or guardians, commending the plan of a five-year course to those "who, from considerations of health, lack of thorough preparation or other cause, have reason to anticipate exceptional difficulty in carrying on all the studies of the regular four-year courses." The circular closed with the following significant remark: "Altogether irrespective of any difficulties, encountered or anticipated, in completing any one of the regular courses within the term of four years, *a five-year course may also be made the means of affording students a larger amount of field-work and laboratory-practice than can be provided for in the present courses.* This may particularly be the case with students who desire to unite some specialty with their regular training." In the same connection it was stated that a committee of the Faculty had been appointed to confer with students contemplating a five-year course, and to have the general oversight of those pursuing such

courses. That committee has been continued to the present time under the chairmanship of Prof. Otis, and subsequently of Prof. Holman.

The plan of five-year courses has steadily grown in favor with students whose financial means made the prolonging of their studies a matter of free choice. Last year the president published an article in the students' magazine, "The Tech," calling attention to the opportunities afforded by the five-year courses for pursuing additional studies in modern languages and in history, political economy and statistics, and dwelling upon the great advantages, alike for mental cultivation and for professional success, to be derived from such studies. At the outset, considerable difficulty was experienced in framing time-tables which would allow the studies of the regular courses to be distributed among the five years without requiring a costly duplication of recitations, lectures, laboratory exercises, etc.; but these obstacles have all been surmounted; and there is now no department which does not offer to all students desiring it the advantages of this arrangement.

The following table shows the number of five-year students by courses, and by years. As there are none in V., VII., VIII., and XII., these courses do not appear in the table: —

Year.	Total.	Course.							Course Undetermined.
		I.	II.	IV.	VI.	IX.	X.	XI.	
First	8	1	2	1	..	..	..	..	4
Second	12	1	8	..	1	..	1	1	..
Third	14	..	3	5	5	..	1	..	..
Fourth	4	1	2	..	..	1	..	..	..
Fifth	3	..	2	..	1	..	..	..	..
	41	3	17	6	7	1	2	1	4

CHANGES IN BUILDINGS AND ROOMS.

No new buildings have been erected during the year now closing. The building which serves as our gymnasium and drill-hall, on Exeter Street, was, during the summer, enlarged by an addition, 25 x 50 feet, devoted to baths, lockers and offices. The bathing and toilet facilities of the gymnasium are now of the first-class, while the clear floor-space, for drill and gymnastic exercises, has been considerably increased. The voluntary use of the gymnasium by the students has apparently doubled during the past year, in recognition of which the Executive Committee have engaged the services of a competent instructor to give those who attend the gymnasium the benefit of his advice and skilled assistance. The students have expressed much gratification at the improved facilities for exercise and athletic training afforded them; and I feel sure the results will be thoroughly wholesome and good.

In the Rogers Building, considerable changes have been effected in the Biological Laboratory by the erection of interior partitions; while on the fourth floor, the large room, No. 44, has been cut into two recitation rooms, to meet the demands arising from the larger number of sections in mathematics and the languages. In the Walker Building, the large laboratories, Nos. 10 and 16, on the first floor, are now being equipped with electric lights, in view of the desire of the students in physics to continue their experiments to a later hour in the afternoon. In the basement of this building an additional laboratory, 29 x 37 feet, has been set apart for the electrical department; while on the third floor, a part of No. 36 has been cut off for the work in gas analysis. No changes have been made in the structure of the Engineering Building, which, I may say, is by every day's use more and more clearly

demonstrating the wisdom alike of its general plan and of its minor arrangements.

The large increase in the number of students has caused an overflow from our previously crowded buildings; and it has been found necessary to hire one of the rooms of the Natural History Building, on the same square with us. We greatly need several additional rooms for the use of instructors, for consultation rooms and administrative offices.

LIBRARIES.

The total accessions to the libraries have been 5,191; of which 2,737 have been received as gifts or in exchange, 2,002 obtained by purchase, and 452 by binding periodicals and pamphlets. The net accessions have been 4,963, of which 4,080 are volumes and 883 pamphlets. The distribution and cost, including binding of the accessions, and the total number of *volumes* in each library, are shown in the following table: —

Library.	Vols. added.	Pph's added.	Cost.	Total No. of vols.
General	467	257	$437 14	2,285
Engineering	637	88	1,067 49	2,750*
Mining	119	20	192 03	1,016
Architectural	67	1	188 33	800*
Chemical	431	135	506 44	4,662
Biological	194	68	155 41	1,133
Physical	568	39	495 34	2,990
Political Science	963	253	718 05	4,395
English	386	3	411 91	1,057
Geological	212	19	48 86	1,200*
Margaret Cheney Room	36	..	.....	500*
Total	4,080	883	$4,221 00	22,788

The numbers marked with an asterisk are only approximate, as these libraries have not yet been catalogued.

The total number of pamphlets is unknown, but certainly exceeds ten thousand.

The total number of periodicals received, excluding annuals, is 338; of these 215 are subscribed for at a cost of $1,143.31, and 123 are received as gifts or in exchange. The number of duplicate copies received is 15, and the number of separate periodicals received 329.

The employment of an assistant has enabled the librarian to undertake the supervision of the binding and some other work which had been previously left to the departments. The change probably has secured greater economy of time and money, and certainly has sensibly relieved the professors and instructors. During the year 613 binding orders were given, covering 905 volumes, at a cost of $936.38. It has been possible, also, to send with each book a copy of its catalogue card, thus keeping the departmental card catalogues up to date in the easiest and surest way.

During the year, 5,638 cards have been added to the main catalogue, which now contains 16,920 cards, covering 18,682 volumes and 3,560 pamphlets. During the summer the cataloguing of the General library was finished, and the Physical library was catalogued. Work on the other libraries was prevented by the receipt of the Rogers library. The librarian has also aided the assistant in the Political Science library in the arrangement of the books on the shelves, and has superintended the preparation of a shelf-list for the Engineering library. The total amount, spent on the libraries, exclusive of salaries, has been $5,515.73.

The principal gift of the year is the very valuable library of the late President William B. Rogers, received from Mrs. Rogers, in addition to the portion of the library received three years ago. The number of volumes received in July was 1,268, of which 1,030 were placed on the shelves, distributed as follows: General Library, 259; Engineering,

51; Mining 15; Architectural, 5; Chemical, 90; Physical, 228; Biological, 117; Political Science, 78; English, 5; Geological, 147; Margaret Cheney Room, 35. Besides these volumes many valuable maps and several hundred pamphlets were received.

Other gifts are as follows: —

From the President of the Institute, 187 volumes and pamphlets, mostly on political economy.

From T. J. Borden, Esq., a set of M. Alcan's works on the textile industries.

From the M. I. T. Civil Engineering Society, a copy of the Century Dictionary.

From Hon. John Costi gan, Minister of Inland Revenue, Canada, a complete set of the publications of his office. A large number of books relating to roads and highways have been purchased during the year for the Engineering library, with a portion of the fund contributed by Colonel Albert A. Pope.

THE CORPS OF INSTRUCTORS.

The catalogue of 1891–92 shows the number of instructors of all grades to be 102, inclusive of those concerned with the mechanic arts, but exclusive of those who are announced as lecturers for the year only. The addition of these would raise the total to 120, made up as follows: —

Professors	12
Associate Professors	13
Assistant Professors	8
Instructors	42
Assistants	27
Lecturers for the year	18
	120

	Civil Engineering.	Mechanical Eng. and App. Mechanics.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Physics and Elect. Engineering.	Biology, Zoölogy, etc.	Mineralogy, Geology, and Geography.	English, History and Political Science.	Language.	Mathematics.	Drawing and Descriptive Geometry.	Mechanic Arts.	Military Tactics.
Professors .....(12)	1	1	1	2	1	1	1	1	..	1	2	..	..	..
Associate Professors(13)	3	2	1	..	1	1	..	..	3	1	1	..	..	..
Assistant Professors (8)	..	2	..	1	1	..	..	1	..	1	1	1	..	..
Instructors .....(42)	3	5	1	1	8	5	1	2	3	2	5	2	3	1
Assistants .....(27)	3	7	..	..	6	3	2	..	..	..	..	3	3	..
Total.....(102)	10	17	3	4	17	10	4	4	6	5	9	6	6	1
Lecturers.....(18)	1	..	1	5	4	4	2	..	1	..	..	..	..	..
Total .....(120)	11	17	4	9	21	14	6	4	7	5	9	6	6	1

These tables show that, with 1,011 pupils, we have one instructor to 10 pupils, if the lecturers for the year be excluded from the account ; one instructor to eight and a half pupils, if the lecturers be included. Either mode of computation shows a very large proportion of instructors, made necessary both by the nature of much of the work pursued in the school, where only a small group of pupils can work with an instructor over a machine, or around a bench or desk, and by the highly specialized instruction given in the later years which tends to form in some cases extremely small sections.

CHANGES IN THE FACULTY AND THE CORPS OF INSTRUCTORS.

The changes in the faculty and the corps of instructors during the year have been chiefly in the nature of promotions among the existing staff. The list above shows a net increase of seven teachers over that appearing in the last report.

Those invaluable officers, Associate Professors Holman and Schwamb, have returned from their year's absence, much improved in health, and have resumed work with their classes. Associate Professor Létang has, in recognition of twenty years of brilliant service, been appointed Professor of Architectural Design. The growing usefulness of the Department of Biology has justified the promotion of Associate Professor Sedgwick to be Professor. Assistant Professor Hofman has been promoted to be Associate Professor of Metallurgy. Two new appointments to the faculty of the school have been made. Dr. Dippold becomes Assistant Professor of Modern Languages; Mr. A. L. Merrill, Assistant Professor of Mechanism. Dr. Dippold has been instructor in the Institute since 1886. Mr. Merrill graduated from the school in the class of 1885; remained as assistant in the Mechanical Engineering department the two succeeding years, and was appointed instructor in 1887.

Mr. Emery, of the English department, having gone abroad to pursue his studies, Mr. Henry Nash Dickinson, A. B., of the class of 1890, at Amherst College, was appointed to his place.

The English department is now earnestly and intelligently at work upon the problem, how to give the best possible instruction in composition and in literature to the pupils of a scientific and technical school, who are necessarily pressed for time by the urgent demands of their professional studies. On the importance, at once, and the difficulty of this problem, I commented at length in my last report. (pp. 23–26.) Professor Carpenter and his assistants are doing their best to achieve a satisfactory result. The courses in English for all regular students have undergone a marked development during the past year. The relation between first-year and second-year English has been more clearly defined, to the advantage of both courses. An experiment, forshadowed in my last report,

has been tried, on a moderate scale, by which the current work of the students of Courses III. and IX. upon professional subjects, has been submitted to Professor Carpenter for criticism. So far, the experiment appears to have been successful. Should further trial prove this course to be practicable, it will go far towards solving the problem referred to. The English library has been strengthened during the year, and has become better adapted to the needs of both the regular and the special students.

The courses in History and Political Economy prescribed for all regular students are given by Professors Levermore and Dewey, with constantly increasing effect. Nothing in the early times of the Institute exhibits more strongly the wisdom which controlled its organization and its general scheme of study than the definitive assignment of a certain, necessarily not a large, space to these studies. In spite of the urgent, the painfully urgent, demand coming up at all times from the professional courses, for more time in which to deal with the constantly increasing matter of interest to them, the faculty have stood firmly by the policy adopted at the beginning; and the allowance of time to English, history, and political economy remains unchanged. Especially is this a subject of satisfaction, now that so many students are resorting to us quite as much for the education and discipline they are to receive as for professional accomplishments. When, in July, I addressed the Convocation of the University of New York, at Albany, on the place of scientific and technical schools in the American system of education, and, after accounting as well as I might for their rapid rise and growth, advanced the proposition that these schools have not only successfully performed their primary work of fitting men to promote and superintend the development of the material resources of the United States, but that they have come, in the course of their own gradual development, to be institutions of a very high order of importance, from the

strictly educational point of view, giving a kind and degree of mental training of the greatest value, and turning out a product of educated men not surpassed by the classical colleges, I was met by several of the most distinguished educators of the country with this reply: "We fully agree with what you have said regarding the highly educational value of the scientific work done in these schools; we admit that study in the natural and physical sciences has many advantages, for the creation of mind and manhood, over the older studies of philosophy, linguistics and dialectics; we agree, too, that the technical applications of science in the schools you represent serve to heighten the interest and quicken the zeal of the student, without sordidly debasing his motives in acquiring knowledge. But we cannot but hold that the entire neglect of philosophical studies by the schools of science and technology is neither eral in spirit nor beneficial in its results." Glad I was to tell them that, in the institution with which I had the honor to be connected, such studies had from the first been incorporated in the curriculum as an integral and necessary part; and that no student had ever yet been graduated from the Massachusetts Institute of Technology, who had not taken substantial courses in literature, history and political science.

In the mathematical department there were two vacancies to be filled at the opening of the school year, in September, due to the retirement of Messrs. Frizell and Woods. It was, however, determined by the Executive Committee to make three appointments, with a view to diminishing the size of the sections in mathematics, a result long desired. The gentlemen appointed for these positions were Mr. Frederick H. Bailey, A. M., of the class of 1887, at Harvard University; Mr. Frank M. Greenlaw, S. B., of the class of 1890, at the Institute, and Mr. Nathan R. George, Jr., A. B., of the class of 1890, at Harvard University.

Since the school opened, however, another vacancy in

the actually instructing staff in this department has occurred, owing to the appointment of Dr. H. W. Tyler, as Secretary, to succeed Mr. Henck, on the latter's resignation. Dr. Tyler still retains his place in the faculty; while his classes for the current term have been taken by his colleagues, in addition to their previous duties. Some other arrangement, not yet consummated, will be made in season for the work of the second term.

It has also been felt to be desirable to reduce the size of the modern language sections; and with a view to this, it was determined by the Executive Committee to appoint an additional instructor in that department for the current year. To this position Mr. Otto Heller was appointed and is now so engaged. Mr. Heller, a native of Austria, was educated in the schools of Prague and Brüx, and in the Universities of Prague and Vienna. Coming to the United States in 1883, he taught in the Amsterdam Academy, N. Y., and in private schools in Philadelphia, until appointed Instructor here. He has published a *First Course in German* (Phil., 1887), edited Stifter's *Haidedorf;* and, in conjunction with Prof. H. A. Clarke, made a metrical translation of Ernst von Wildenbruch's *Harold.*

While the appointment of Mr. Heller has afforded some relief in the matter of the size of the classes in modern languages, those classes are still too large for the best effect; and I hope means will be found, another year, for still another instructor in this department. The work in history and political science devolving upon Professor Levermore having increased beyond his power of carrying it alone, Mr. Chas. F. A. Currier was appointed Instructor in this department. Mr. Currier graduated from Harvard University in 1887, and in 1888 received the degree of A. M. from that institution. After further study at Harvard, chiefly in constructional history, Mr. Currier spent a year at Berlin with Professors Gneist, Brummer, and others, and then a year at Paris in the *École Libre des Sciences Politiques.*

With a view to promoting the study of Highway Engineering, Mr. Fred. E. Foss has been appointed Instructor in the department of civil engineering, on the Pope foundation, and assigned to road making and repairing as a specialty. Mr. Foss graduated from Bates College in 1883, and received the degree of A. M., from the same college, in 1886. He graduated in Civil Engineering from the Institute of Technology with the class of 1886. From 1886 to 1889 he was employed as resident engineer and as assistant engineer of maintenance of way, on the Chicago, St. Paul & Kansas City Railway, having charge of construction work of various kinds, including the Galena tunnel. From November, 1889, till the summer of 1891, he was engaged as resident engineer on the Chicago Union Pacific Railway, in charge of construction of yards at Chicago.

The following named gentlemen, assistants last year, have been promoted to be Instructors: George W. Hamblet, in Mechanical Engineering; Frank A. Laws, in Physics.

The list of assistants for the current year is as follows: in Civil Engineering: Franklin Knight, Nathan R. Pratt, Luis F. Verges. In Mechanical Engineering and Applied Mechanics: John O. DeWolf, Howard C. Slater, Fred A. Cole, Carleton A. Read, James Swan, Clifford M. Tyler, Charles P. Wetherbee. In Chemistry: Edward C. Holton, William S. Davenport, Willis R. Whitney, Horace Burrough, Jr., Ernest A. Hersam, Oscar W. Pickering. In Physics and Electrical Engineering: Harry M. Goodwin, William L. Smith, Arthur N. Mansfield. In Biology: George V. McLauthlin, Franklin W. White. In Drawing and Descriptive Geometry: Harrison I. Cole, Walter E. Hopton, Hamilton Rice. In the Mechanic Arts: James D. Littlefield, Wesley B. Churchill, Charles L. Conant.

SUMMER SCHOOLS.

Summer School of Geodesy and Topography. — This school was conducted by Professors Burton, Porter, Niles, and Crosby and Mr. Robbins, at Delaware Water Gap, during the month of June. The topographical and geodetic work consisted of the survey of an area of about one square mile along the Delaware River, and the measurement of a base line over one-half mile long, with triangulations from the base-line to the surrounding hills. The base-line was measured by apparatus designed by students of the school, involving some new and interesting features. The results proved remarkably satisfactory. The hydraulic work of the school comprised about a dozen measurements of the flow of the Delaware River, at two different places, with floats and meters. The geological work consisted in a study of the geology of the surrounding country in its relation to the topographical features, and the construction of an accurate geological section about two miles long. Excursions were also made to the steel works at Bethlehem, to Mauch Chunk, and the engineering features of interest in that vicinity, and to the Bangor slate quarries. The school was attended by sixteen students, and was in every respect successful and satisfactory.

Summer School of Metallurgy. — This year the school was held in New Jersey and Pennsylvania. The instructors present were Professors Richards and Hofman. Most of the time was passed at Pittsburgh, where the students spent nearly a month in studying the various processes of the iron and steel manufacture. Opportunities for metallurgical study, such as occur at Pittsburgh, are hardly to be found at any other point in the world; and the eager scholars from the Institute made the most of them. At all the following named works our party were cordially received and were granted every facility: —

The Orford Copper Company, The Bethlehem Iron

Company, The Lucy Furnaces, The Isabella Furnaces, The Eliza Furnaces, Schoenberger Speer & Co., The Upper Union Mills, The Crescent Steel Company, The Vesuvius Iron and Nail Works, The Pennsylvania Lead Company, The American Iron and Steel Works, The Homestead Steel Works, The Standard Mines of H. C. Frick Coke Company, The Edgar Thompson Steel Works and Blast Furnaces, The Oliver Iron and Steel Company, The Latrobe Steel Works, The Fort Pitt Foundry, The Pittsburgh Reduction Company, The Carbon Iron Company, and the Union Storage Company.

Course I. *Civil Engineering.* — The course of study in this department has not been altered in any important respect during the past year. The staff of professors and instructors is the same as heretofore, with the addition of Mr. Fred. E. Foss, who was this year appointed Instructor in highway engineering. The development of the work of instruction in this branch is progressing as rapidly as possible; and the class-room work will be considerably extended this year. Special lectures on this branch were given last spring by Mr. E. P. North of New York, and Mr. H. T. Buttolph of Buffalo; and it is expected that similar lectures by specialists will be given from time to time.

The equipment of the hydraulic laboratory has been increased during the past year by several important pieces of apparatus: one, permitting of the delicate measurement of the velocity in any part of a flowing jet, as well as the measurement of the size of the jet; another, serving for carrying on experiments upon the flow through short tubes or mouth-pieces, with measurements of the pressure at the throat. Designs are in progress for several other instruments which will be added this year. As all the apparatus is original, and has to be specially constructed, great care is taken to design the instruments so that they can be used for as great a variety of purposes as possible, and also, that all possible contingencies which

can arise in their use may be adequately provided for. Among apparatus which has been presented or loaned to the laboratory should be mentioned a Pelton water motor, presented by the company, and a variety of apparatus loaned by Mr. John R. Freeman, which he used in his recent extended experiments on the discharge through nozzles and fire-hose. The laboratory continues to be the subject of frequent inquiries from engineers and from other schools of science.

The work in surveying and geodesy remains essentially the same as heretofore, but some laboratory work in connection with it is being introduced. Room 44, in the Engineering Building, will, this year, be fitted up as a laboratory for experiments on the coefficients of expansion of the actual tapes used in measuring base lines, the accurate examination of bubble tubes, the collimation of telescopes, and the accurate adjustment of instruments generally. The outfit of instruments has been increased this year by a fine reflecting circle.

Course II. *Mechanical Engineering.* — Besides the constant and gradual development that takes place from year to year, the following are matters that should be specially mentioned, regarding this department of the school. In my last report attention was called to the need, in the Engineering Laboratories, of an Emery testing machine, of 200,000 or, better still, 300,000 pounds capacity. I have now to report that this need will shortly be supplied, a horizontal machine of this kind, of 300,000 pounds capacity, having been contracted for, at a cost of $12,660. The machine is to be constructed by William Sellers & Co., of Philadelphia, and contains all the essential principles of the famous 800,000 pounds testing machine, at the Watertown Arsenal, which was built by Albert H. Emery. Since the time of the building of the Government machine, the Yale & Towne Manufacturing Company, of Stamford, Conn., has made a few vertical machines of this type, having a

capacity of 150,000 pounds. At the present time, the firm of William Sellers & Co., of Philadelphia, are undertaking their manufacture; and, while they have built one or two of 100,000 pounds capacity, this is the first which they have undertaken of a capacity so great as 300,000 pounds.

The extreme delicacy and accuracy of this type of machine is generally recognized. This delicacy and accuracy of working, together with the fact that the machine under construction is to have a capacity of 300,000 pounds, and will be suitable for testing a compression specimen eighteen feet long, and a tension specimen twelve feet long, will enable the department of applied mechanics to undertake and carry out a kind and amount of experimental investigation which it could not otherwise perform, and to obtain a large number of results of value in practical engineering work, of a kind that could not possibly be obtained by means of machines of smaller capacity. The machine is to be placed on the north side of the basement room of the laboratory for testing the strength of materials, the machinery now occupying this portion of the room being transferred to other parts of the laboratory. Owing to the fact that the floor of the laboratory is exceptionally strong, the machine will be set directly on the floor, and will require no special foundation. It is expected to be in place in season for the second term's work.

In last year's report attention was called to the fact that a considerable increase had been made in the time devoted to instruction in Naval Architecture. I have now to report that the course has already been developed to such an extent that, during the present school year, the time devoted to it is two and one-third times as much as last year; and it is intended again to increase the time very considerably for the next school year. Professor Peabody, who is in charge of this work, has this year had assigned to him, Mr. Charles P. Wetherbee, a graduate of the class of 1891, as assistant for this special purpose. The course has

been carried forward so far that it now includes, not only a more extended treatment, than heretofore, of the theory of the stability of vessels, together with a study of methods of construction, but, also, applications made to the case of a government ship of good design. The assignment of a suitable assistant has made it possible to work up a considerable amount of material, and to put it in a form which will be permanently useful for purposes of instruction; so that next year an extended course will be offered in the Theory of Naval Architecture with proper drawings and calculations, in a manner similar to that given in the government schools of England and France. The department is now in possession of drawings, lines of ships, displacement-sheets, and other material necessary for carrying on the work; but the future development of the subject will require a very large addition to this material. It is also very desirable that there shall be provided a set of models, showing the framing and construction of iron and steel ships, together with sections of the angle irons, z-irons, beams, etc., and examples of the various joints and methods of riveting. The possession, at some future time, of an experimental tank, say, thirty feet wide, ten feet deep, and three hundred to four hundred feet long, with the various towing and dynamometrical apparatus, profiling machines for making models of ships from their lines, and other appurtenances, would enable this school to introduce laboratory methods into this work, and to obtain results of practical value to the profession.

The present affords an appropriate occasion to remark that there is always a gradual and constant development going on in this, as in other, departments of the Institute, which, while it does not conspicuously appear on a comparison of one year with the next, is seen very strikingly in a comparison of longer periods. Improvements which singly attract little attention are accumulated until they amount to most important gains; gains so great that a

student of three or four years ago would, on comparing the course as at present given with that which he took, be surprised at the improvement, especially in the later years of the course. And this improvement has taken place with no greater demand than formerly upon the time and strength of the student. That such an advance could be effected simply shows how much science there may be in teaching science. Thus, if we compare the Mechanical Engineering Course, as given at present with that given a few years ago, we find:

(1.) That it has been found possible to transfer considerable of the work on valve-gears from the lecture-room to the drawing-room; and this fact, together with the time gained by a better systemization of the course in thermodynamics and steam, has rendered it possible to insert, in the third-year course on Steam, — (*a*) more work on the construction of engines; (*b*) work on compound and multiple engines; (*c*) work on steam-injectors and steam-pumps, part of which was formerly given in the fourth year course on steam and part in the marine option; also to insert a study of the gas engine in the fourth-year course.

(2.) That, considerable as is the amount of data on the strength of materials used in construction, obtained by means of experiments on a practical scale in different parts of the world during the last few years, the department of applied mechanics has been constantly developing its class-room exercises close up with this advance, which causes the work done at present in the fourth-year applied mechanics to be far superior to that done a few years ago.

(3.) That the work done in all of the three options has been very much developed and rendered more practical, so that a student who took any one of them a few years ago would find the greater part of the present work new and in advance of that done when he was here. All three options of the fourth year in mechanical engineering are taken by students. Thus, we have in the class of 1892,

ifteen taking the Mill option; five, the Locomotive option; ıine, the Marine option, of whom six are taking, also, the :ourse in Naval Architecture.

While a considerable amount of experimental investiga- ion is constantly being carried on in the laboratories, it nay be worth while specially to mention a series of careful ınd elaborate tests made upon the new triple-expansion :ngine, the results of which were communicated to the American Society of Mechanical Engineers, in June, 1891, ɔy Professor Peabody. By way of smaller additions to the apparatus of the laboratories, which have not yet been noted in the report, may be mentioned a machine for testing the effect of repeated bending on the strength and elasticity of iron and steel, by means of which Professor Sondericker has been enabled to carry on a considerable amount of research into this matter; also, a machine for testing the strength of cloth. Another addition to the Mechanical Engineering Laboratory is found in a duplex pump, presented by the New York Air Brake Company.

Professor Schwamb will give, this year, to the students of the fourth-year class, some instruction in shop management; and it is intended within a short time to develop this feature of the instruction very considerably. I am indebted to Henry R. Towne, Esq., of Stamford, Conn., for valuable suggestions regarding the manner in which such a course should be organized and conducted.

I have already referred to the resignation of Instructor Purinton, the promotion of Instructor Merrill to be Assistant Professor of Mechanism, and the welcome return of Associate Professor Schwamb after his year's absence. To Professor Merrill has been assigned all the work in mechanism and cotton machinery, except that done personally by Professor Schwamb. Instructor Miller has been relieved from the drawing-room work and placed in charge of the engineering laboratory; while Mr. G. W. Hamblet, promoted from Assistant to Instructor, has taken up the

drawing-room work left by Mr. Miller. The present organization of the mechanical engineering department is strong and efficient.

Course III. *Mining Engineering and Metallurgy.* — The preparation of lithographic notes upon the professional subjects is progressing. This year the course in ore-dressing will be mainly, if not wholly, drawn up in lithographic notes. In the John Cummings Laboratories important additions have been made to the apparatus, namely, — a Brückner revolving roasting furnace, a pair of Collom jigs, and three new muffle assaying furnaces. The first of these was a gift to the department; and the second was furnished at an extremely low price by the Chicago Iron Works. Both were specially designed and constructed for the mining department, and contain some features which, from alike the educational and commercial point of view, are new and valuable. The additional apparatus adds greatly to the facilities of the laboratory for the most efficient tests of ores by the most modern appliances. The new muffle-furnaces render the assaying more efficient, as well as much more comfortable for class work. A course on technical machinery is now being given by Professor Peabody, in the second term of the fourth year, to the mining engineering students.

Course IV. *Architecture.* — The growing success of this, always first-ra , department constitutes one of the most striking features of the Institute. In spite of illness continued through the greater part of last year, Professor Chandler, with his able corps of assistants, succeeded in keeping up the interest and the practical progress of his pupils to a remarkable degree; and the present year has opened with the largest number of students which the architectural department has ever known, notwithstanding the discontinuance of the two-year Partial Course, which it was anticipated would cause an immediate falling-off in attendance. The raising of the standard of admission for

pecial students has resulted in attracting a large class of older men, of considerable office experience. This has perceptibly added to the power of the department. A circular will shortly be issued which will further explain, for the information of intending special students, the conditions upon which they may enter this course, and will give advice as to the studies they should pursue in preparation for it. A greater number of students than ever before are taking the five-year course, in architecture. The opportunity of securing additional instruction and practice in design, sketching, and water color, and of becoming intimately acquainted with the department library, is proving a strong incentive to the students to protract their stay at the Institute.

The library of the department is a first-rate working library; and its current additions are made with much care, to meet practical and everyday needs. Mrs. William B. Rogers has given four large and beautiful Roman photographs which have been framed and hung upon the walls. The Technology Architectural Society has presented to the library Smith's Dictionary of Greek and Roman Antiquities; also, a German and a French Dictionary. The construction of diagrams and charts, for use in the various courses of lectures, has been continued on the most liberal scale. These are of a permanent character, relating particularly to construction-details, architectural history, graphical statics, orders, shades and shadows. The Executive Committee have arranged to have an accomplished draughtsman kept steadily at work, month after month, until the whole series shall be completed, when it will form an addition to the resources of the department whose value can scarcely be estimated. More than almost any other department of the school, this is already suffering from confined space, notwithstanding the two great drawing-rooms three years ago placed at its disposal. Every desk is taken, and the facilities in the

way of lecture rooms and of rooms for the storing and exhibition of models and the materials of construction, are altogether inadequate. Even the library-room is too small for the superb collections of books and photographs now belonging to the department. During Professor Chandler's illness, many of his classes were successfully conducted by Mr. W. A. Rodman, of this city.

Course V. *Chemistry.* — The general state of the chemical work of the school is satisfactory. Ever since the assignment of Prof. Drown to the charge of the entire chemical department, there has been progress in each branch of the service, while a better relation has been established between the different parts. The most noticeable changes of the year have been as follows: —

Associate Professor Norton, who has hitherto given the instruction in both organic and industrial chemistry, was, at his own desire, at the close of the past year, relieved of the organic work. This relief to Professor Norton came none too early. The growth in both the departments under his charge during the few preceding years had been so great as nearly to crush him; and I feel almost guilty for allowing him to carry such a burden for so long a time. No definitive arrangements regarding the instruction in organic chemistry have yet been made; but for the present year we have been so fortunate as to secure the services of Professor Henry B. Hill, of Harvard University, who is now giving the instruction to the fourth-year class.

During the past year, the laboratory of industrial chemistry has been completely rearranged, and its capability for work largely increased by the introduction of additional evaporating apparatus and other facilities. A separate machine-room has been provided, and the machinery has all been set therein. The work in textile coloring has undergone further development during the past year; and a two-color printing machine, presented to the Institute through the liberality of the Pacific Mills Corporation, will

ɔon be in operation. The facilities for teaching gas ıalysis have been increased both by the purchase of new ɔparatus and by the enlargement of the room devoted to ıis purpose. In addition to the instruction given to the ıemists in this important branch of analysis, it is now ɔssible to offer to the students in the engineering courses struction and practice in the analysis of furnace gases. the department of sanitary chemistry, the analysis of the ıters of Massachusetts for the State Board of Health is ll carried on, as is also the analytical work connected ith experiments on water filtration now being conducted ɔy the city of Boston.

Courses VI. and VIII. *Physics and Electrical Engineering.* — In the department of physics and electrical engineering there has been, as in previous years, a continued ɔrogress in the amount and character of the work done. The increased number of assistants, at the service of the ɔhysical department during the past and present year, has :nabled it to increase very materially the value of the nstruction in the physical laboratory, owing to the closer upervision of individual students and to the certainty that he apparatus would be at all times in condition to give ood results. With the welcome return of Professor Holman he new course of lectures and laboratory exercises in heat ıeasurements, arranged for previously to his departure a ear ago, has begun, thus filling an important gap in the ıstruction given to the students in chemical engineerıg and allied courses. With the advance in the grade of ıstruction in theoretical electricity given in the third ɛar to the students in Courses VI. and VIII., it has come ı be impossible longer to give the same instruction to udents in Course V., as well, since these do not have the ɛcessary mathematical preparation. A separate class llowing a different course has, therefore, been organized meet their needs. Mr. F. A. Laws, instructor in physics, s taken charge of this class.

A very important change has also been made in Course VIII. in the substitution of analytical mechanics for applied mechanics. This change is one which has been desired for many years; but not until now has it been possible to carry it out, owing to the excessive demands made by the more purely professional courses upon the time of the department of mechanics. The new course is in charge of Professor Lanza. This change necessitates an earlier introduction of the subject of differential equations, which has likewise been arranged. Separate instruction in thermodynamics has also been provided for the students in Course VIII. by Professor Peabody. Owing to the inability of Messrs. Jacques and Blake to continue their respective courses on telephone engineering and electro-motors, Messrs. Hammond V. Hayes, Ph. D., and J. P. B. Fiske, S. B., have been appointed lecturers for the current year on those subjects. It is hoped that we may secure a considerable lengthening of these important courses of lectures.

The outfit of the physical laboratory has been very materially increased by the addition of several dynamo-machines and electro-motors, together with much new apparatus for electrical testing. The department has also been able to make use of the large dynamo machine in the engineering laboratory for purposes of instruction in testing, through the co-operation of the department of mechanical engineering.

The difficulties which were alluded to in last year's report, arising from the jarring of the Walker building, are no less serious than heretofore, although there has been no increase. A great convenience has been added to the laboratory during the past year by its connection with the mains of the Edison Electric Illuminating Company. Although the current furnished from them is not sufficiently steady for use in delicate testing, it enables us to carry on work of certain kinds in the evening, or during vacation, without the necessity of running our own dynamos and

large engine. It may also offer a partial solution of the trouble from occasional overloading of our dynamos and engine on dark days, when there is a great demand for electricity for general lighting in addition to that used in laboratory operations. The most serious difficulties that we have to contend with arise from the very large number of students taking the full course in electrical engineering in the fourth year. The increase from twenty-seven students in 1890–91 to forty-one in 1891–92, is severely taxing our resources, especially as concerns suitable rooms and sufficient material for thesis and other advanced work. The department would find itself seriously embarrassed were it not for the cheerful help afforded by the students themselves in surmounting the various obstacles that arise, and the patience exercised by them in cases where unavoidable delay is experienced. Should our present number of students continue, a very considerably increased amount of room, apparatus, and machinery will be essential to further increase in the efficiency of our work.

Course VII. *Biology.* — The work of the biological department has been successfully conducted by Professor Sedgwick, assisted by Dr. E. G. Gardiner on the zoölogical side, and by Mr. G. V. McLauthlin, of the class of 1888, in the laboratory. Professor Sedgwick has also continued to serve as biologist to the State Board of Health; and a portion of the sanitary work of the Board has been done in the biological laboratory of the Institute. During last winter, Lowell was visited by a severe epidemic of typhoid fever, and Professor Sedgwick was called to make an investigation of the drinking water of that city. That he was able to bring that investigation to a satisfactory conclusion was largely due to the thorough modern equipment of the chemical and biological laboratories of the Institute. His report upon this epidemic forms an important contribution to sanitary science. Possibly som members of the corporation do not realize how far the Institute of Technology

have chosen historical, economic, and philosophical studies, as extra work; and still others have carried on courses of reading in such subjects under the direction of Course IX. instructors. I have already in this report expressed the hope that the excellent facilities here offered for historical, political, and philosophical study will, in a near future, induce very many of our students, including our best scholars, to extend their courses to five years. Mr. W. Z. Ripley, of the class of 1890, who remained at the Institute the year after his graduation, for economic and historical study, was, at the beginning of the present year, elected a Fellow in the school of Political Science at Columbia College; and is now pursuing his studies in that institution with the highest promise of success. The library of political science has profited greatly, as have so many of the other departmental libraries, by Mrs. Rogers' gift of books. Course IX. has been much strengthened by the appointment, already recited, of Mr. Currier, to whom have been assigned the classes in comparative politics, constitutional history, and international law.

Course X. *Chemical Engineering.* — Students were graduated from this course for the first time in May, 1891. Up to the beginning of the fourth year, the work consists substantially of studies and exercises belonging either to the mechanical engineering or to the chemical course. While the work of the senior year has much in common with the course in mechanical engineering, it has little in common with the course in chemistry. It is designed to deal with chemical problems from the manufacturing rather than the analytical side. A course of reading, lectures, and recitations upon applied chemistry begins with the first term. This course is designed to last through twelve weeks, and is being given for the first time this year. In this course, the applications of organic chemistry to manufacturing are discussed in much greater detail, and with more attention to the machinery used, than is possible in the elementary instruc-

tion in industrial chemistry given in the third year. The industries specially considered are the manufacture of petroleum products, fats, fatty oil and soaps, essential oils and resins, starch and glucose, the fermentation industries, milk products, paper-making and tanning and the making of glue. This is to be followed by a course, given for the first time last year, in which various engineering problems are discussed from a chemical point of view. The leading topics considered in this course are fuels, their composition and consumption, boiler waters and incrustations, corrosion of boilers, and other similar questions. This instruction will occupy eighteen weeks.

The optional instruction upon heat measurements offered to the students of the course, by Professor Holman of the physical department, is being given this year, for the first time, to two of the last year's graduates in Course X. Determinations of the heat of combustion of fuels, and the testing and use of certain pyrometers have been begun in the laboratory, accompanied by lectures upon the same subjects. In the second term, Professor Peabody discusses with the students of this course, the special machinery which falls within the scope of chemical engineering. This course of instruction, which is termed "technical machinery," includes a discussion of winding, blowing, and pumping engines, air compressors and compressed air engines, air and ammonia refrigerating machines and absorption refrigerating apparatus, rock and diamond drills and steam stamps, centrifugal extracting and drying machines, pressing and filtering machines, and multiple-effect evaporators.

The laboratory work peculiar to Course X. begins about Nov. 1 and continues through the year. Its scope and character are sufficiently indicated by the titles of the graduating theses of the Class of 1891, which are as follows: "A study of the effect of a live steam feed-water purifier upon the composition of the feed-water." "The production of chlorine and sodium hydrate by the elec-

trolysis of common salt." "On the heat of vaporization of ammonia." "The relative illuminating effects of different forms of gas burners," and "An investigation of certain problems connected with the bisulphite process for making chemical fibre."

The number of students taking this course shows a steady increase. The new course already stands fourth in point of numbers, as regards the division of the students in the second year, having seventeen regular students. It is evident that a special laboratory, independent of the laboratory of industrial chemistry, must be provided in the near future, if the unlooked-for growth in numbers in the course of chemical engineering continues. This laboratory must be a laboratory for research and must be equipped with a view to the study and testing of the machinery and appliances used in industrial chemistry. It will necessarily differ widely in its aims from the industrial chemical laboratory which is designed to give to students practice in the making of chemicals. The work connected with Course X. now demands most of the time of Professor Norton. The interest taken in the instruction given by us in industrial chemistry and in chemical engineering is shown by the frequent applications made to us by other educational institutions for advice and information.

Course XI. *Sanitary Engineering.* — In this course, established in 1889, students this year become, for the first time, candidates for the degree of the Institute. The scheme of studies pursued has been essentially as outlined at the beginning. That is to say, the students have followed in the main the regular civil engineering course; but, at the expense of a certain amount of time taken from bridge and railroad work, have prosecuted, for three years, a connected line of studies and laboratory practice in chemistry and biology as applied to sanitary engineering. They have thus received a special and valuable training for dealing with sanitary problems of water supply and

vance in this direction. The facilities for palæontology must receive immediate attention. The geological library has been increased by gifts from Mrs. Rogers and by other accessions; but until additional shelf-room is provided, it cannot be catalogued or satisfactorily arranged.

By the courtesy of J. H. Maiden, Esq., curator of the Technological Museum of Sydney, N. S. W., we have received an important collection of Australian wools, of all classes, numbering about four hundred samples. The collection is prepared in such a manner as greatly to enhance its usefulness. It forms a most welcome addition to our collections.

THE NEED OF ENDOWMENTS.

The continued growth of the school makes even more startling the danger which menaces the Institute of Technology from the lack of adequate endowments; it might almost be said, of any endowments at all. So tempting have been the educational opportunities offered to this school at every stage of its development, so imperative and various have been the demands coming from the industries of Massachusetts and New England, that there has been no possibility of stopping long enough at any point in our extraordinary growth and development, to accumulate considerable financial means, as a security for the future and as a reserve against disaster. Year by year, with few exceptions, all that could be provided has had to go to make room for the ever-increasing throng of students resorting to our halls, or to purchase the costly machines and apparatus required to keep the instruction at the Institute continually improving, up to the full needs of professional practice. Since the opening of the Institute in 1865, all that its friends could possibly give has had to go into buildings, furniture, plant, books, drawings, machinery and apparatus, except only the sum of $485,908.69, which is all we have of income-yielding property.

With this, compare our expenditures of last year, which amounted to $238,676.91, although a rigid economy was exercised, and although our professors and teachers are very inadequately remunerated for services that are literally invaluable. Our annual expenditure is thus seen to be equal to one-half the total productive property of the school! Such a situation is most dangerous. An institution, doing the work which the Institute of Technology is carrying on, ought to have an ample endowment, as a guarantee of the future; as a reserve against disaster; as a means of securing the continually progressive improvement of all its departments and services; and as a fund for reducing the tuition of deserving but needy students. Does not such a situation make a strong claim upon all who believe that this school of Industrial Science has done, is doing, and is capable, in still higher grades yet, of doing a noble work, alike for education and for industrial progress, to contribute by every means in their power to the adequate permanent endowment of the Institute?

THE GRANT FROM THE UNITED STATES.

In my report a year ago, I called the attention of the Corporation to the provisions of an Act of Congress approved Aug. 30, 1890, "for the more complete endowment and maintenance of colleges for the benefit of agriculture and the mechanic arts now established, or which may hereafter be established, in accordance with an Act of Congress approved July 2, 1862." It was then assumed, as a matter of course, that the Massachusetts Institute of Technology would share in the benefits of the grant of 1890, as in those of the grant of 1862; but it was suggested that, should other legislation be required to enable the Commonwealth to avail itself of the new grant from the Treasury of the United States, the Corporation of the Institute should memorialize the General Court at its approaching session,

o award to the Institute, as the College of Mechanic Arts or the State of Massachusetts, a somewhat larger share of the annual income thus to be received from the United States. This suggestion met the approval of the Corporation, which, by vote of the tenth of December, 1890, authorized its officers to memorialize the Legislature in that sense. The following memorial was accordingly presented to the Legislature :—

To the Honorable Senate and House of Representatives of the Commonwealth of Massachusetts, in General Court Assembled:

"The undersigned, officers of the Massachusetts Institute of Technology, do, on behalf of the said Institute, being thereunto specially authorized and empowered, memorialize your honorable bodies as follows, to wit :—

"By an Act of Congress dated July 2, 1862, provision was made for the creation and endowment of a college or colleges of 'agriculture and the mechanic arts' in each State of the Union.

"By an Act of the General Court of Massachusetts, approved April 27, 1863, it was provided that of the income of the fund so constituted in and for this Commonwealth, under the national grant as recited, one third be annually paid to the Massachusetts Institute of Technology, and two thirds to the Agricultural College at Amherst. This Act has been continuously in operation since 1863; and the Institute of Technology is still in receipt of one third of the annual income of the national grant of 1862, the payment into its treasury during the last fiscal year, upon that account, having been $4,960.82.

"By an Act of Congress approved Aug. 30, 1890, entitled 'An act for the more complete endowment and maintenance of colleges for the benefit of agriculture and the mechanic arts now established or which may be hereafter established, in accordance with an Act of Congress ap-

proved July 2, 1862,' the sum of $15,000 was granted to the Commonwealth of Massachusetts for the fiscal year 1889-90, and for each succeeding year, except that the sum of $1,000 is yearly to be added to the grant until a maximum of $25,000 shall be reached, after which the annual grant shall remain at that sum and limit. As one of the two beneficiaries under Act of Congress, approved July 2, 1862, and the Act of the General Court of Massachusetts, approved April 27, 1863, the Massachusetts Institute of Technology through us, its agents and representatives thereunto duly authorized, petitions your honorable body that at least one half the annual grant from the Treasury of the United States, under the Act of Aug. 30, 1890, may be set apart and awarded to the Institute of Technology, as the College of Mechanic Arts in and for the Commonwealth.

"In asking that the share of the new grant assigned to the Institute of Technology, may be greater than that conferred by the Act of April 27, 1863, your memorialists have, they believe, no more than a due regard to the importance of the manufacturing and mechanical interests of Massachusetts, and to the extent of the work of instruction, with its necessary accompanying expenditures, which is carried on in this School of Industrial Science.

"The national grant of July 2, 1862, is frequently spoken of as if it were for the establishment of 'Agricultural Colleges,' solely; but this can only be attributed to ignorance of the history and the actual provisions of that act. The Mechanic Arts are firmly, and indissolubly joined with Agriculture, alike in the title, and in the body of the law; and that, too, upon no unequal terms. If agriculture was first mentioned, it was because one, or the other, must have necessarily such precedence; and because, taking the United States as a whole, agriculture was then, as it still remains, the chief single industrial interest of the people. But while this is true of the country taken together,

it is not true of Massachusetts, where manufacturing and mechanical industries employ six times as many of the people as does agriculture. We do not adduce this preponderance of industrial interest on the side of manufactures, as constituting a reason why this institution, which is the chartered College of Mechanic Arts for Massachusetts, should receive a disproportionate share of the bounty of the National Government; but we do desire most respectfully to urge that not less than a full half of the new grant should be so assigned.

"At the time the Act of April 27, 1863, was passed, the proportions, therein established, viz: one third to the Institute of Technology, two thirds to the Agricultural College, might have seemed not unreasonable. The Institute of Technology then existed only upon paper. It was, as yet, a mere scheme; and many were doubtful whether it would ever be much more. It had not a pupil or a teacher, a building or a foot of land which it could call its own. Even those then most sanguine of its future had but a faint conception of what it might become. To-day, after a quarter of a century of zealous and disinterested effort, the Massachusetts Institute of Technology stands the largest scientific and technical school in the United States, and one of the most important in the world. Although this school is resorted to by students from thirty-eight States of the Union and from nearly a score of foreign countries and states, yet of its nine hundred and thirty-seven pupils, at present pursuing courses in civil, mechanical, electrical, mining, chemical and sanitary engineering, architecture, chemistry, biology, physics, and geology, five hundred and seventeen, or fifty-five per cent of the whole number, are residents of the Commonwealth. While hundreds of Massachusetts boys, here educated, have gone out all over the land to practise their professions, it yet remains true that not less than forty-six per cent of the graduates of the school are still citizens of the

Commonwealth, engaged upon its railroads, in its mills and factories, in the sanitary and engineering service of its cities, or in other occupations connected with the development of the material interests of the State.

"While we can thus point with pride to the services which the Institute of Technology has rendered and is still rendering to the Commonwealth, it remains to be said that its wants are in proportion to the extent and value of the work it has undertaken to perform. Its needs are so great because it is itself so much needed. As yet without any considerable endowments, the Institute is compelled to draw its support chiefly from tuition fees, which are inadequate to supply all the demands of the most advanced instruction.

"There is no single department of the school in which large additional expenditures might not immediately be made with the highest advantage to the industries of the Commonwealth. Your memorialists will not further occupy the attention of the General Court, but hold themselves ready, whenever called upon, to present whatever information may be desired regarding the history, condition, organization and plans of the Institute." (*Signed by the President, Secretary and Treasurer.*)

Should it be my privilege to present to the Corporation the President's Annual Report for December, 1892, I shall deem it a part of my task at that time to recite and comment upon the legislative history of this memorial; but inasmuch as the matter of the national grant of 1890 is now before the Supreme Court of Massachusetts, on a bill brought by the Agricultural College, at Amherst, asking that the treasurer of the Commonwealth be compelled to pay over to that institution the entire sum received, and to be received, under the Act of 1890, I will now merely say that the legislature passed an act which was approved by the Governor, June 11, 1891, in the following terms: —

[CHAP. 423.]

AN ACT TO ASSENT TO THE PURPOSE OF AND TO ACCEPT THE GRANTS OF MONEY AUTHORIZED BY CONGRESS FOR THE MORE COMPLETE ENDOWMENT AND SUPPORT OF COLLEGES FOR THE BENEFIT OF AGRICULTURE AND THE MECHANIC ARTS.

Be it enacted, etc., as follows:

SECTION 1. The Commonwealth of Massachusetts hereby assents to the ırpose of the grants of money authorized by the Act of Congress, entitled An Act to apply a portion of the proceeds of the public lands to the more ›mplete endowment and support of the colleges for the benefit of agriculture ıd the mechanic arts, established under the provisions of an act of Congress ›pproved July second, eighteen hundred and sixty-two," said act being chap- :r eight hundred and forty-one of the acts of the first session of the Fifty-first ongress and approved on the thirtieth day of August in the year eighteen undred and ninety.

SECTION 2. The Commonwealth of Massachusetts hereby accepts the nnual grant of moneys made by the United States as set forth and defined n said Act of Congress, and the treasurer and receiver-general of this Commonwealth is hereby designated to receive the same annually, to be applied ›y him under and for the purposes of said act; and the Massachusetts Institute of Technology is hereby authorized to receive one third and the Massachusetts Agricultural College two thirds of said grant of money, unless the courts should decide that the Act of Congress granted all said money to the Massachusetts Agricultural College.

SECTION 3. The Governor of the Commonwealth is hereby authorized and instructed to give due notice thereof to the government of the United States.

SECTION 4. This act shall take effect upon its passage. [*Approved June 11, 1891.*]

Under the provisions of this Act the Institute of Technology would receive $5,000.00 for the year 1890; $5,333⅓ for 1891; $5,666⅔ for 1892, and so on by annual increments of $333⅓, up to a final maximum of $8,333⅓ in 1900.

CONCLUSION.

It is now full ten years since, at the call of the Corporation, I was introduced to this body by my illustrious predecessor, Dr. Rogers, and became the President of the Institute of Technology. With all my heart I make acknowledgment of the kindness, the generosity, the scru-

pulous consideration with which the Corporation, individually and collectively, have made good their pledge, then given, to stand by me in my administration. The duties of the office have been rendered comparatively light by the confidence and the strong support which have uniformly been extended to me by my colleagues on this Board.

I long ago said that the greatest crisis through which a young institution of learning is called to pass, is, not with respect to its general scheme of work, not with respect to its finances, not with respect to its Faculty, but with respect to its Board of Trustees. It was inevitable that the Massachusetts Institute of Technology, so young yet so ambitious, attempting so much with so little in the way of experience to go by, and so little to do with, should pass through crises of each kind indicated; but the extraordinary success which has crowned this educational enterprise proves that, alike in its general scheme of work, in its Faculty and staff of instruction, and in the control and direction exercised by the Corporation, the Institute, in spite of all misfortunes and all mistakes, has been singularly fortunate.

Especially do I desire to express my deep sense of the services rendered to the Institute, as well as of the official confidence and personal kindness uniformly extended to myself, by the Executive Committee, since the constitution of that body in 1883. The close continuous attention given to the affairs of the school by the members of the Executive Committee has been one element of great strength in our recent growth. Habitually every member is present at every meeting held; and thus the Institute is given the full benefit of all the knowledge and experience of the whole committee, acting in perfect harmony, with a clear understanding of the situation, and with the most zealous regard for the good of the school.

TREASURER'S REPORT.

STATEMENT OF THE TREASURER.

The Treasurer submits the annual statement of the financial affairs of the Institute for the year ending Sept. 30, 1891.

By deed of Mrs. Martha Ann Edwards, dated Nov. 21, 1876, there were conveyed to the Institute two-thirds of the estate at Lenox, Mass., known as "Highlawn," subject, however, to certain life estates and other reservations. Those having the life estates in this property have since died, and during the past year the Institute has in compliance with the provisions of the original deed sold its interest in the property for the sum of thirty thousand dollars, which sum has been invested and constitutes the Martha Ann Edwards Fund.

During the year there has been paid to the Institute by the executors of the will of the late Mrs. Charlotte B. Richardson a legacy of thirty thousand dollars for the benefit of the department of Industrial Chemistry. This by the terms of the will is to be called the Charlotte Billings Richardson Fund.

This legacy was paid by the transfer to the Institute of one hundred and forty-eight shares of stock in the Boston & Albany Railroad Company at its market value at the time, two hundred and two and one quarter dollars per share, and the payment in cash of the balance, amounting to sixty-seven dollars.

In October, 1890, an agreement was made between Mr. Albert A. Pope and the Institute. By this agreement Mr. Pope generously undertakes to pay to the Institute for five years the sum of twelve hundred dollars annually, and the Institute agrees to use the sums so received for instruction in street building and highway engineering.

The following bonds have been paid or sold: —

Grand Rapids, Newaygo & Lake Shore Railroad 8s (paid at maturity)	$34,000 00
Burlington & Missouri River Railway in Nebraska 6s (called and paid)	1,000 00
Atchison, Topeka & Santa Fe Railroad Income 5s $8,900 (sold)	5,629 25
	$40,629 25

With the proceeds the following securities have been bought: —

$37,000 Chicago Junction Railway & Union Stock Yards 5s	$33,655 00
$2,000 New York & New England Railroad 1st, 6s	2,240 00
$4,000 Kansas City, Fort Scott & Gulf Railroad 7s	4,400 00
	$40,295 00

The income of the Institute for the past year has been divided at the rate of $5\frac{84}{100}$ per cent among the funds to which it belongs.

Besides the gifts from the estates of Mrs. Edwards and Mrs. Richardson and from Mr. Pope, already referred to, other gifts have been received, as follows: —

Mrs. William B. Rogers, for periodicals	$ 200 00
Augustus Hemenway, Esq	1,000 00
Alumni of Institute toward William B. Rogers Scholarship Fund	650 00

The net result of the year has been an expenditure over income of $3,440.59, which has been charged against Massachusetts Institute of Technology Account.

GEORGE WIGGLESWORTH, TREAS., *in account with*

GENERAL STATEMENT OF RECEIPTS AND DISBURSEMENTS

Dr.

Cash balance Sept. 30, 1890		$5,392 71
From Augustus Lowell for Lowell Courses	$3,600 00	
" " " " C. Kastner's salary	2,500 00	
" " " " Lowell School of Design	1,000 00	
		7,100 00
RECEIPTS FOR CURRENT EXPENSES.		
Income of funds for salaries	$4,818 00	
" " " " scholarships	4,070 00	
" " " " Joy "	200 00	
" " " " Swett "	400 00	
" " " " Library	275 00	
" " " " general purposes	11,055 52	
" " Rogers Memorial Fund	12,511 25	
Students' fees	177,818 65	
State Agricultural Fund	5,640 97	
Laboratory breakage and supplies	4,525 12	
Rents, per Table. (Page 12)	6,330 00	
Gifts	1,200 00	
Interest	2,646 93	
Pope Fund used	418 88	
Boston University	1,150 00	
Sale printed Lecture Notes	2,176 00	
Profit and Loss, expenses more than income (see per contra)	3,440 59	
		238,676 91
BEQUESTS, NEW TRUSTS, ETC.		
Martha Ann Edwards General Fund	$30,000 00	
Charlotte Billings Richardson Industrial Chemistry Fund	30,000 00	
Albert A. Pope, for Street Building and Highway Engineering, amount not used	781 12	
Letter Box Fund, balance	82 67	
Income James Savage Fund, not used	218 94	
" James H. Mirrlees Fund, " "	24 27	
" William Barton Rogers Fund, " "	301 49	
" Elisha Thacher Loring Fund, " "	83 68	
" Richard Perkins Fund, " "	378 23	
Income Charlotte Billings Richardson Fund, not used	825 00	
Increase Wm. Barton Rogers Scholarship Fund	650 00	
		63,345 40
SALE OF SECURITIES, GENERAL FUND.		
Burl. & Mo. Riv. R. R. in Neb., Bond called	$1,000 00	
Atchison, Topeka & Santa Fé, Incomes	298 88	
Transferred to Rogers Memorial Fund	1,687 50	
		2,986 38
SALE OF SECURITIES WM. B. ROGERS MEMORIAL FUND.		
Grand Rapids, Newaygo & L. S. R. R. 8s matured	$34,000 00	
Atchison, Topeka & Santa Fé, Incomes	5,330 37	
		39,330 37
SUNDRIES.		
Students' Notes Receivable paid	$1,257 00	
Income General Funds credited to Advance Bond Premium Account	2,412 12	
Income Wm. B. Rogers Memorial Fund credited to Advance Bond Premium Account	1,650 75	
		5,319 87
		$362,151 64

THE YEAR ENDING SEPTEMBER 30, 1891.

Cr.

d for Lowell Courses	$3,600 00	
" " Charles Kastner's salary	2,500 00	
" " Expense Lowell School of Design	1,245 52	
		$7,345 52

EXPENSES.

Salaries, per Table. (Page 12)	$160,229 95	
" paid from the Pope Fund	350 00	
Scholarships	4,270 00	
" paid from Swett Fund	200 00	
" " " Savage "	200 00	
Repairs, per Table. (Page 12)	6,948 66	
General Expense, per Table. (Page 13)	9,180 83	
Fuel	8,002 61	
Water	1,220 20	
Gas	1,758 21	
Printing and Advertising	3,123 02	
" Lecture Notes	2,401 21	
" Annual Catalogue	1,480 92	
Rents paid Boston & Albany R. R. Co.	180 00	
" " Natural History Society	600 00	
Laboratory Supplies and Libraries, per Table. (Page 12)	25,857 92	
Society of Arts	305 18	
Interest, $5\frac{84}{100}$ per cent on $211,784.20, funds not in stocks and bonds	12,368 20	
		238,676 91

INVESTMENTS, ETC.

Securities, General Account, 148 Shares Boston & Albany R. R. Co.,	$29,933 00	
Kansas City, Fort Scott & Gulf R. R. 7s,	2,200 00	
C. L. Flint Scholarship Fund, more than income	40 23	
		32,173 23

SECURITIES BOUGHT FOR WM. B. ROGERS MEMORIAL FUND.

Chicago Junction Ry. and Union Stock Yards 5s, 37,000.00	$33,762 92	
New York & New England R. R. first 6s, $2,000.00,	2,274 33	
Kansas City, Fort Scott & Gulf R. R. 7s, $2,000.00,	2,289 44	
Transferred from General Securities	1,687 50	
		40,014 19

SUNDRIES.

Gymnasium Building Addition	$1,627 25	
Paid on account New Boiler No. 2	4,392 41	
Notes Receivable	25,476 75	
Profit and Loss, per contra	3,440 59	
		34,937 00
Cash Balance, Sept. 30, 1891		9,004 79
		$362,151 64

The following account exhibits the property held by the Institute, as per Treasurer's books, Sept. 30, 1891: —

Investment of the W. B. Rogers Memorial Fund.		
Saginaw & Western R. R. 6s	$50,000 00	
Chicago Junc. Ry. & Union Stock Yards 5s ($37,000)	33,655 00	
Burlington & Mo. River R. R. 4s ($30,000)	25,787 50	
Kansas City Belt R. R. 6s	25,000 00	
Mo. Valley, Blair Ry. & Bridge Co. 6s	20,000 00	
Atchison, Topeka & Santa Fé R. R. 4s ($18,000)	15,372 30	
Kansas City, Clinton & Springfield R. R. 5s	16,000 00	
Omaha & Southwestern R. R. 8s	7,000 00	
Republican Valley R. R. 6s	5,400 00	
Cin., Ind., St. Louis & Chicago R. R. 6s	4,000 00	
Ottawa, Oswego & Fox River R. R. 8s	2,000 00	
New York & New England R. R. First 6s	2,000 00	
Kansas City, Fort Scott & Gulf R. R. 7s	2,000 00	
Kansas City, Memphis & Birmingham R. R. 5s ($2,000)	1,905 00	
Lincoln & Northwestern R. R. 7s	1,000 00	
Atchison & Nebraska R. R. 7s	1,000 00	
Advances to Bond Premium account	15,439 35	
Bonds	$227,559 15	
220 shares Chicago, B. & Quincy R. R. Stock	22,000 00	
		$249,559 15
Investment of the Joy Scholarship Fund.		
Mass. Hospital Life Insurance Co.	$5,000 00	
Deposits in Savings Banks	3,159 63	
		8,159 63
Investment Swett Scholarship Fund.		
Mass. Hospital Life Insurance Co.		10,000 00
Investment of Other Trusts.		
Atchison, Topeka & Santa Fé R. R. 6s	$50,000 00	
Quincy & Palmyra R. R. 8s	25,000 00	
Burlington & Mo. River (Nebraska) R. R. 6s	18,000 00	
" " " (Land Grant) R. R. 7s	15,000 00	
Chicago, Burlington & Quincy R. R. 7s	7,000 00	
" " " " 4s ($6,000)	5,100 00	
Milwaukee & St. Paul R. R. $7\frac{3}{10}$	3,000 00	
Cincinnati & Indiana R. R. 7s	2,000 00	
Chicago, Burlington & Northern R. R. 5s	2,000 00	
Kansas City, Fort Scott & Gulf R. R. 7s	2,000 00	
International & Great Northern R. R. 6s	1,000 00	
Union Pacific R. R. 6s	1,000 00	
Advances to Bond Premium account	4,748 91	
Bonds		135,848 91
Amount carried up		$403,567 69

Amount brought up		$403,567 69

STOCKS.

8 shares Boston & Albany R. R.	$29,933 00	
4 " Chicago, Burlington & Quincy R. R. . .	15,400 00	
2 " Cocheco Manufacturing Co.	6,000 00	
5 " Old Boston National Bank	5,510 50	
5 " Hamilton Woollen Co.	5,000 00	
2 " Morris & Essex R. R.	4,100 00	
7 " Essex Co.	4,050 00	
5 " Pennsylvania Coal Co.	3,750 00	
5 " Everett Mills.	3,150 00	
5 " New York & Harlem R. R.	2,000 00	
5 " Pittsburg, Fort Wayne & C. R. R. . .	2,000 00	
5 " Consolidated Gas Co., New York . . .	1,447 50	
		82,341 00

REAL ESTATE.

gers Building	$315,726 88	
alker Building	190,492 44	
nd on Garrison Street . . .	$50,840 00	
orkshops " "	52,416 49	
	103,256 49	
nd on Trinity Place	$76,315 69	
gineering B'ld'g, Trinity Place .	106,616 87	
	182,932 56	
mnasium Building.	5,340 61	
		797,748 98
uipment, Engineering Building	$16,555 24	
" Workshops	20,628 56	
		37,183 80

SUNDRIES.

tes Receivable	$26,976 75	
dents' Notes	2,400 00	
w Boiler No. 2 Account	5,000 00	
well School of Design	461 97	
ih Balance, Sept. 30, 1891	9,004 79	
		43,843 51
		$1,364,684 98

The foregoing Property represents the following Funds and Balances and is answerable for the same.

The Income of the following is used for the general purposes of the Institute: —

William Barton Rogers Memorial Fund	$250,225 00	
Richard Perkins Fund	50,000 00	
George Bucknam Dorr Fund	49,573 47	
Martha Ann Edwards "	30,000 00	
Nathaniel C. Nash "	10,000 00	
Sidney Bartlett "	10,000 00	
Robert E. Rogers "	7,680 77	
Albion K. P. Welch "	5,000 00	
Stanton Blake "	5,000 00	
McGregor "	2,500 00	
General Institute "	36,028 00	
		$456,007 24

The Income of the following is used towards paying salaries: —

Nathaniel Thayer, for Professorship of Physics,	$25,000 00	
Jas. Hayward, for Professorship of Engineering,	18,800 00	
William P. Mason, " Geology	18,800 00	
Henry B. Rogers, for General Salaries	25,000 00	
		87,600 00

SCHOLARSHIP TRUSTS.

Richard Perkins Fund	$52,255 20	
James Savage "	11,472 34	
Mrs. Susan H. Swett Fund	10,182 95	
William Barton Rogers Fund	8,835 51	
Joy Fund	8,159 63	
Elisha Thacher Loring Fund	5,241 52	
Charles Lewis Flint Fund	5,137 35	
Thomas Sherwin Fund	5,000 00	
Farnsworth Fund	5,000 00	
James H. Mirrlees Fund	2,647 27	
		113,931 77

OTHER TRUSTS

Charlotte Billings Richardson, Industrial Chemistry Fund	30,825 00
Charles Lewis Flint, Library Fund	5,000 00
Albert A. Pope, Street Building and Highway Engineering, Fund, balance	781 12
Letter Box Fund, balance	82 67

MISCELLANEOUS.

Notes Payable	$20,000 00	
Students' Deposits	450 00	
Subscription of 1887	123,500 00	
M. I. T. Stock Account	526,507 18	
		670,457 18
		$1,364,684 98

COMPARATIVE STATEMENT OF FUNDS, ETC.

	Sept. 30, 1890.	Sept. 30, 1891.
or general purposes	$426,007 24	$456,007 24
. . . . .	87,600 00	87,600 00
ships	112,315 39	113,931 77
. . . . .	5,000 00	5,000 00
te Billings Richardson Industrial		
ustry Fund		30,825 00
A. Pope Street Building and Highway		
Fund		781 12
Box Fund		82 67
'ayable	20,000 00	20,000 00
s' Deposits	450 00	450 00
ption of 1887	123,500 00	123,500 00
. Stock Account	529,947 77	526,507 18
	$1,304,820 40	$1,364,684 98
e.	59,864 58	
sting of: —		
Ann Edwards Fund	30,000 00	
te Billings Richardson Fund . .	30,000 00	
" " Income . .	825 00	
e Wm. Barton Rogers Scholarship		
. . . . .	650 00	
ship Funds, not used	966 38	
e Albert A. Pope Fund, balance . .	781 12	
Box Fund, balance	82 67	
	$63,305 17	
ss. Expenses more than Income .	3,440 59	
		$59,864 58

INCOME FROM GENERAL INVESTMENTS, AND APPLICATION THEREOF.

Applied to Salaries	. . . . .	$4,818 00	From Dividends, Old Boston National Bank . .	$330 00
" " Scholarships	. . . . .	4,070 00	" State Tax returned, Old Boston National Bank	81 82
" " Library	. . . . .	275 00	" Railroad Bonds	8,054 00
" " General Purposes	. . . .	11,055 52	" Dividends, Pittsburg, Ft. W. & C. R. R. Stock,	140 00
" " Increase of Funds	. . . .	1,791 38	" " Pennsylvania Coal Co. . .	600 00
" " Advances to Bond Premiums	. .	2,412 12	" " Everett Mills.	192 50
			" " Essex Co.	297 00
			" " Cocheco Mfg. Co. . . .	240 00
			" " Consolidated Gas Co., N. Y. .	75 00
			" " Chicago, Bur. & Q. R. R. . .	654 50
			" " New York & Harlem R. R. . .	210 00
			" " Hamilton Woollen Mills . .	300 00
			" " Morris & Essex R. R. . . .	287 00
			" " Boston & Albany R. R. . .	592 00
			" Interest on Funds not in Bonds and Stocks @ $5\frac{84}{100}\%$ the rate on earnings invested .	12,368 20
		$24,422 02		$24,422 02

INCOME FROM WILLIAM BARTON ROGERS MEMORIAL FUND, AND APPLICATION THEREOF.

Paid Massachusetts Institute of Technology 5%		Received Income from Railroad Bonds . .	$13,227 00
on Amount of Fund ($250,225 00) . .	$12,511 25	" Dividend 220 Shares Chicago, Bur-	
Credited to Advances Bond Premiums . .	1,650 75	lington & Quincy R. R.	935 00
	$14,162 00		$14,162 00

DETAILS OF SOME ITEMS IN TREASURER'S CASH ACCOUNT.

Rents.

Huntington Hall, for Lowell Lectures	$3,200 00	
Lowell School of Design	1,800 00	
Chauncy Hall School, for Gymnasium	300 00	
State Board of Health, for use of Laboratories	875 00	
Boston Water Works, use of Laboratory	100 00	
Use of Lecture Rooms and Gymnasium	55 00	
		$6,330 00

Department Supplies.

Chemical Department	$7,611 15	
Physical "	4,852 85	
Mining "	1,218 52	
Mechanical Eng'r'g "	1,919 37	
Applied Mechanics "	687 85	
Civil Engineering "	2,768 00	
Biological "	865 87	
Geological "	280 75	
Architectural "	1,261 42	
Drawing "	45 32	
Mathematical "	12 20	
English "	1,258 81	
Workshops	1,790 60	
Modern Languages	141 90	
Periodicals	1,143 31	
		$25,857 92

Salaries.

Instruction	$131,894 30	
Administration	13,606 74	
Labor	14,728 91	
		$160,229 95

Repairs.

Department Improvements: —			
Chemical Department	$1,069 73		
Physical "	374 30		
Mechanical Eng'r'g "	261 78		
Mining "	909 53		
English "	79 85		
Architectural "	334 98		
Civil Engineering "	363 83		
Drawing "	203 72		
Biological "	234 41		
Workshops "	314 75		
		$4,146 88	
Amount carried forward		4,146 88	

Amount brought forward . . .		$4,146.88	
ı		272 53	
gers and Walker Buildings . . .		256 48	
mnasium		69 74	
and Secretary's Offices . . .		139 73	
om		18 96	
ineering Building		54 40	
Valker Building		35 75	
. . . . .		97 00	
. . . . .		1,857 19	
			$6,948 66

General Expenses.

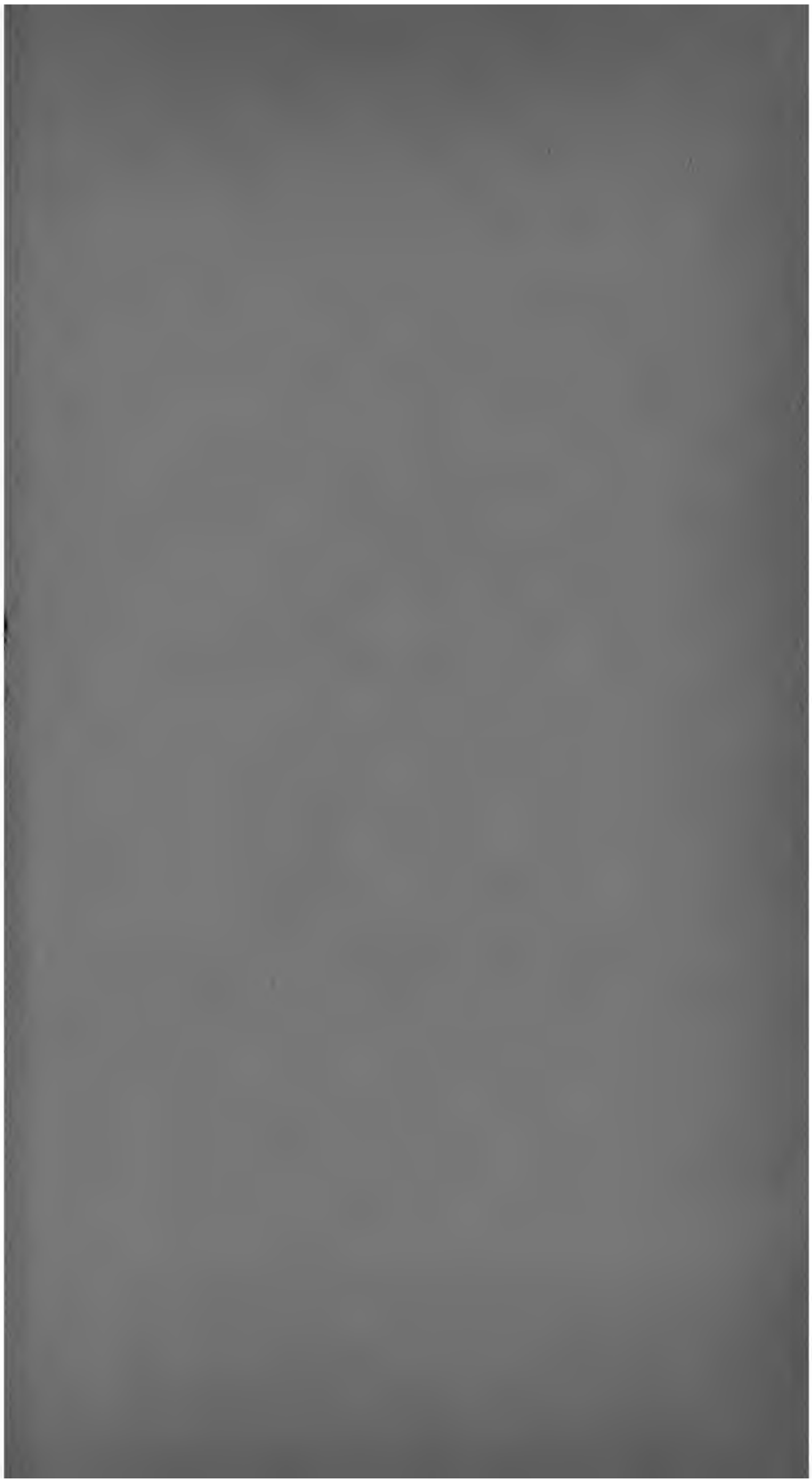
. . . . .		$338 20	
ades		126 39	
hting: —			
tc.	$166 97		
nished	150 61		
		317 58	
ers		1,020 69	
. . . . .		36 45	
a Supplies: —			
. . . . .	$199 43		
aste	56 16		
Valve	38 75		
ter	52 00		
s	30 85		
		377 19	
Supply Pipe, Engineering Building .		113 94	
epartment Equipment: —			
n-dye Kettles		352 50	
ish, etc.		289 24	
Rent of		53 48	
Commissions, and Expense of Drills .		368 60	
xaminations		945 75	
. . . . .		50 00	
. . . . .		332 34	
rges		373 20	
Supplies for General Library . .		319 91	
ass		76 90	
. . . . .		109 70	
. . . . .		1,199 60	
. . . . .		185 50	
nd Office Supplies		541 84	
Exhibit at Conference on Manual			
. . . . .		61 44	
Quarterly Subscriptions to 100 copies,			
ing		170 00	
Amount carried forward . .		$7,760 44	

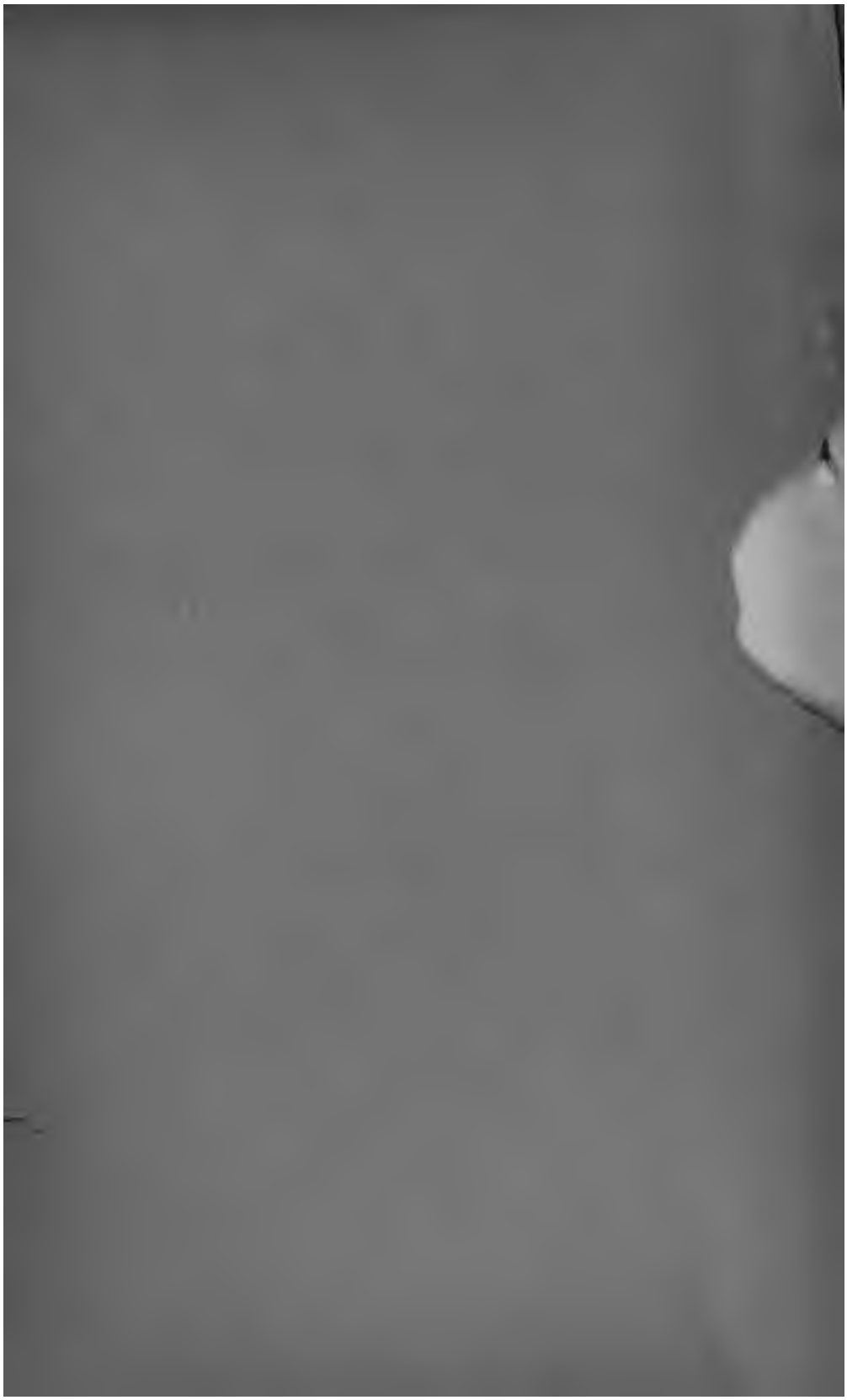
Amount brought forward . . .	$7,760 44	
Lunch Room Supplies: —		
Crockery, etc.	139 07	
Janitor's Supplies: —		
Brushes, Pails, Dusters, Soap, etc. . . .	344 56	
Towels, etc.	40 43	
Mats, Waste Baskets, etc.	75 82	
Boston Electric Time Co.	27 00	
New Boiler, No. 2, Depreciation on account of .	470 05	
Income Real Estate, Lenox, Mass., balance . .	1 10	
Sundries	322 36	
		$9,180 83

BOSTON, November 30, 1891.

examination of the accounts of the Treasurer of the
ıchusetts Institute of Technology for the year ending
30, 1891, has been made, and they are found to be
:tly cast, and with proper vouchers. The Ledger
ces agree with the Trial Balance. We have verified
'idences of personal property held by the Institute.

FREDERIC W. LINCOLN,
CHARLES C. JACKSON,
JAMES P. TOLMAN,
Auditing Committee.





MASSACHUSETTS

TUTE OF TECHNOLOGY.

ANNUAL REPORT

OF THE

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ANNUAL REPORT

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MEMBERS OF THE CORPORATION.

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Secretary.*
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Treasurer.
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JOHN D. RUNKLE.
ALEXANDER H. RICE.
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JAMES M. CRAFTS.
JACOB A. DRESSER.
THOMAS L. LIVERMORE.
A. LAWRENCE ROTCH.

On the Part of the Commonwealth.

HIS EXCELLENCY GOV. WILLIAM E. RUSSELL.

HON. WALBRIDGE A. FIELD, *Chief Justice of the Supreme Court.*

HON. JOHN W. DICKINSON, *Secretary of the Board of Education.*

* Communications relating to the School should be addressed to Dr. H. W. Tyler, Secretary of the Institute.

COMMITTEES OF THE CORPORATION.

Executive Committee.

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GEORGE WIGGLESWORTH. } *Ex Officiis.*

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PERCIVAL LOWELL. JOHN D. RUNKLE.
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ALEXANDER H. RICE. HOWARD STOCKTON.
FREDERIC W. LINCOLN.

Trustees of the Museum of Fine Arts.

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ARTHUR ROTCH.

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DESMOND FITZGERALD.

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DESMOND FITZGERALD.
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JAMES P. TOLMAN.

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CHARLES J. PAINE.

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THORNTON K. LOTHROP.

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A. LAWRENCE ROTCH.

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HENRY L. PIERCE.
JOHN W. DICKINSON.
FRANCIS A. WATERHOUSE.

Department of Modern Languages.

FRANCIS A. WATERHOUSE.
NATHANIEL THAYER.
ARTHUR ROTCH.

Department of Mathematics.

HOWARD STOCKTON.
HOWARD A. CARSON.
PERCIVAL LOWELL.
DESMOND FITZGERALD.

Departments of Chemistry and Biology.

SAMUEL CABOT.
CHARLES C. JACKSON.
JAMES M. CRAFTS.

Department of Chemical Engineering.

ARTHUR T. LYMAN.
HIRAM F. MILLS.
SAMUEL CABOT.
CHARLES W. HUBBARD.

To the Corporation of the Massachusetts Institute of Technology:—

The year upon which I am now to report has been one of steady growth, and, in the main, of prosperity. There has been an increase in the attendance at the Institute, which has required an increase in the instructing staff. Very important changes, long maturing, have been introduced into the curriculum which have enabled every department of the school to supply some urgent want of advanced or specialized instruction. A new building has been put up, which affords ample and pleasant quarters for the department of Architecture, while the withdrawal of that department from the Walker Building has left room for a much-needed expansion of the departments of Physics and Chemistry. All around, all through, the Institute of Technology has, I believe, grown larger and stronger in the twelve months now closing, except only in the matter of its finances. The new building has, indeed, been paid for, and a small fund provided for its maintenance. This is something; this is, in itself, much; and we have deeply to thank some of the friends of the Institute who have again shown noble generosity in our behalf; but towards the permanent endowment of the school we have made little or no progress. The millions which should furnish the means of present usefulness, the opportunity for continual expansion and improvement, and the security of the future, have not yet been placed in our hands.

I would not strike this note to weariness; but it is important that it should be understood throughout the community that the Institute of Technology is as yet substantially unendowed; and that, until very large sums have been added to our resources, the school must remain all the time in peril of its life, and those who direct its destinies must continually be in the mental attitude of shrinking under an impending blow. It needs not to be said that this is not a fortunate mental attitude for those who have to conduct a great work. If during these twenty-seven years the Institute of Technology has been a potent factor in the development of the educational system of America; if it has led the world in the introduction of laboratory practice in general chemistry, in physics, and in metallurgy; if it has done

well by its great army of students; if it has opened successful careers to hundreds upon hundreds of young men; if it has contributed freely to the development of the industries of Massachusetts and of New England; if it stands to-day the largest, most complete school of its class anywhere to be found, the acknowledged model upon which institutions are being organized, both in the New World and in the Old, — then it would certainly seem that, in a community so lavish in its beneficence, so intelligent in its selection of the objects of that beneficence, the Institute cannot long be suffered to lack that ample and substantial foundation which will not only afford security for its future, but will be the source of strength and confidence in the present daily conduct of its affairs.

Yet the year has not passed altogether without addition to our means. Since the date, Oct. 1, of the Treasurer's report, the sum of $20,000 has been received, in accordance with the bequest of the late T. O. H. P. Burnham, of Boston. Mrs. Susan Covell, of Springfield, has given the sum of $5,000 for the establishment of a perpetual free scholarship in memory of her nephew, the late William F. Huntington, a graduate of the Institute in the class of 1875. By the will of the late Prof. T. Sterry Hunt of New York, from 1871 to 1878 Professor of Geology in this institution, certain securities, the value of which is not yet ascertained, are bequeathed the Institute of Technology as a scholarship fund. The bequest of Mr. Samuel E. Sawyer, of Gloucester ($4,000), mentioned in my report of 1890, is still in litigation. Meanwhile one very important addition to our resources has been received through the act of the General Court of Massachusetts, of June 11, 1891, and a decision of the Supreme Judicial Court of the Commonwealth thereupon, to which I shall now refer.

In my report of last year, I noted the fact that the Massachusetts (Amherst) Agricultural College had brought a bill in the Supreme Judicial Court of the Commonwealth, asking that the State Treasurer be compelled to pay over to that institution the entire sum received and to be received under the act of Congress, approved Aug. 30, 1890, entitled "An Act to apply a portion of the proceeds of the public lands to the more complete endowment and support of the colleges for the benefit of agriculture and the mechanic arts

established under the provisions of an act of Congress, approved July 2, 1862." The case of the Massachusetts Agricultural College *vs.* Marden (State Treasurer) was argued in the Supreme Court in January last, and the court handed down its decision on the 29th of March following, dismissing the petition of the Agricultural College. The text of the decision will be found in the appendix to this report. It will be seen that the decision confirms every claim of the Institute. This decision left the act of the Legislature, approved June 11, 1891 (the text of which was printed in my last annual report), to go into effect; and the Institute of Technology has consequently received its one-third share of the first four annual instalments of the national grant, made to the State of Massachusetts under the act of Aug. 30, 1890. The aggregate amount thus received by the Institute is $22,000. The one-third share of the grant to come to us the present year will be $6,333.33, constituting a much-needed and most welcome addition to our resources.

THE GRADUATING CLASS.

Of the 132 graduating members of the class of 1892, 22 graduated in civil engineering, 26 in mechanical engineering, 4 in mining engineering, 12 in architecture, 7 in chemistry, 36 in electrical engineering, 6 in biology, 1 in physics; 7 graduated from the department of general studies, 4 in chemical engineering, 6 in sanitary engineering, and 1 in geology. All courses of the school were thus represented in the award of diplomas.

THE ENTERING CLASS.

The new year has witnessed a still further increase in the number of students in the school. The total registration this year, as by the catalogue now in press, amounts to 1,060, against 1,011 last year, a gain of 49. The following table exhibits the number of the students in the school each year, from the opening of the Institute to the present time: —

Year.	No. of Students.	Year.	No. of Students.
1865–66	72	1879–80	203
1866–67	137	1880–81	253
1867–68	167	1881–82	302
1868–69	172	1882–83	368
1869–70	206	1883–84	443
1870–71	224	1884–85	579
1871–72	261	1885–86	609
1872–73	348	1886–87	637
1873–74	276	1887–88	720
1874–75	248	1888–89	827
1875–76	255	1889–90	909
1876–77	215	1890–91	937
1877–78	194	1891–92	1011
1878–79	188	1892–93	1060

STUDENTS BY CLASSES.

The aggregate number of students for 1892–93 is divided among the several classes as follows: —

Graduate students, candidates for advanced degrees	3
Regular students, Fourth Year	138
" " Third Year	144
" " Second Year	175
" " First Year	314
Special students	286
Total	1060

Assigning the special students to classes, according to the predominant studies pursued by them, we reach the following statement of the division of the whole body among the several years:

Class.	Regular.	Special.	Total.
Graduates of the M. I. T., candidates for advanced degrees	3		3
Fourth Year	138	25	163
Third Year	144	99	243
Second Year	175	114	289
First Year	314	48	362
Total	774	286	1060

STATISTICS OF EXAMINATIONS.

Of the 1,060 students of the present year, 442 were not connected with the school in 1891–2; 18 had been connected with the Institute at some previous time, and returned to resume their places in the school; 40 were admitted provisionally, without examination; 1 was admitted by examination to the second year, 32 as special students; 67 were admitted on the presentation of diplomas certificates from other institutions.

Excluding from consideration those who were admitted but have not, in fact, entered the school, 65 in number, the following was the final result of the examinations held in June and September: —

Admitted clear	207	
" on one condition	49	
" on two conditions	21	
" on three conditions	8	
" more than three conditions	2	287
Rejected		54
		341

EXAMINATIONS AT DISTANT POINTS.

In addition to the entrance examinations held in Boston in June and September, 1892, examinations were also conducted, in June, at Albany, Chicago, Cincinnati, Denver, Detroit, Easthampton, Exeter, Montreal, New York, Philadelphia, Pittsburg, Poughkeepsie, San Francisco, St. Louis, St. Paul, and Washington.

RESIDENCE OF STUDENTS.

Thirty-nine States of the Union, besides the District of Columbia, Utah, and New Mexico, are represented on our list of students. Of the total number of 1,060, including special students, 606 are from Massachusetts, or 56.9 per cent of the whole; 124 are from other New England States; 330 from outside New England, of whom 23 are from foreign countries.

The following table shows the number of students of each specified class from each State or foreign country: —

States.	Candidates for Advanced Degree.	Fourth Year.	Third Year.	Second Year.	First Year.	All Regular Students.	Special Students.	Total.
Alabama	....	..	..	1	1	2	2	4
Arkansas	....	..	1	...	1	2	...	2
California	....	2	3	3	1	9	5	14
Colorado	....	1	1	1	...	3	4	7
Connecticut	....	3	6	3	8	20	7	27
Delaware	....	..	1	...	1	2	...	2
Dist. Columbia	....	..	2	...	2	4	...	4
Florida	....	1	1	1	1	4	...	4
Georgia	....	..	..	2	...	2	1	3
Idaho	....	..	..	...	...	...	1	1
Illinois	....	4	5	4	12	25	15	40
Indiana	....	..	2	1	1	4	1	5
Iowa	....	2	2	3	...	7	3	10
Kansas	....	..	..	...	...	...	1	1
Kentucky	....	1	2	...	1	4	3	7
Louisiana	...	..	..	...	...	...	2	2
Maine	....	6	2	6	17	31	8	39
Maryland	...	..	..	1	2	3	3	6
Massachusetts	3	87	79	103	195	467	136	603
Michigan	....	2	..	2	1	5	5	10
Minnesota	...	3	5	2	2	12	1	13
Missouri	....	2	..	1	6	9	4	13
Nebraska	....	..	..	2	1	3	1	4
Nevada	....	..	1	1	...	2	1	3
N. Hampshire	....	4	5	5	10	24	5	29
New Jersey	....	2	1	...	1	4	7	11
New Mexico	....	..	..	1	1	2	...	2
New York	....	4	9	6	14	33	17	50
North Carolina	....	..	..	..	...	...	1	1
Ohio	....	4	3	6	10	23	16	39
Oregon	....	..	..	...	2	2	...	2
Pennsylvania	....	3	4	8	4	19	6	25
Rhode Island	....	4	3	6	4	17	7	24
South Carolina	....	...	1	...	...	1	...	1
Tennessee	....	...	...	...	...	...	1	1
Texas	....	...	...	...	3	3	2	5
Utah	....	...	...	...	...	...	1	1
Vermont	....	...	...	...	1	1	3	4
Virginia	....	...	...	...	1	1	3	4
Washington	....	...	...	2	1	3	...	3
West Virginia	....	1	...	...	...	1	1	2
Wisconsin	....	...	2	...	4	6	3	9
Foreign Countries.								
Belgium	....	...	...	...	1	1	...	1
Bulgaria	....	1	...	...	...	1	...	1
Cent'l America	....	...	1	...	...	1	...	1
England	....	...	1	...	...	1	...	1
France	....	...	...	...	...	...	1	1
Hawaiian Isl'ds	....	...	...	...	...	...	2	2
Holland	....	...	...	2	...	2	...	2
Japan	....	1	...	...	...	1	...	1
Mexico	....	...	...	...	...	...	1	1
New Brunswick	....	...	...	1	...	1	...	
New So. Wales	....	...	...	...	...	...	1	1
Prov. Ontario	....	...	...	...	...	...	2	2
Prov. Quebec	....	...	1	...	3	4	1	5
Scotland	....	...	...	...	...	...	1	1
Spain	....	...	...	...	1	1	...	1
Turkey	....	...	...	1	...	1	...	1
Total	3	138	144	175	314	774	286	1060

A table showing the number of students in each year from and including 1886, coming from each State or Territory and from each foreign country, may not be without interest and instruction: —

States.	1886.	1887.	1888.	1889.	1890.	1891.	1892.
Alabama	...	...	...	1	...	2	4
Arkansas	2	3	2	2	3	3	2
California	8	9	13	10	14	19	14
Colorado	...	2	2	6	4	7	7
Connecticut	16	29	28	36	31	30	27
Delaware	1	...	...	...	1	...	2
Dist. of Columbia,	4	4	9	9	7	4	4
Florida	...	...	...	2	3	3	4
Georgia	3	2	1	1	2	2	3
Idaho	...	...	...	...	...	1	1
Illinois	19	29	37	33	34	32	40
Indiana	2	...	1	3	6	3	5
Iowa	6	3	6	4	9	10	10
Kansas	2	...	...	...	2	2	1
Kentucky	4	2	3	4	4	8	7
Louisiana	...	...	2	4	8	5	2
Maine	20	24	26	30	29	27	39
Maryland	2	2	4	4	7	7	6
Massachusetts	402	429	494	533	517	565	603
Michigan	5	10	12	13	16	13	10
Minnesota	4	6	8	10	12	13	13
Mississippi	1	...	...	...	...	..	...
Missouri	1	5	7	8	8	12	13
Montana	...	...	...	...	1	...	...
Nebraska	2	4	2	1	1	1	4
Nevada	1	...	...	...	1	3	3
New Hampshire	26	19	24	21	23	24	29
New Jersey	7	11	8	13	11	16	11
New Mexico	...	...	2	...	...	1	2
New York	24	35	31	25	40	40	50
North Carolina	...	...	1	2	1	1	1
Ohio	21	21	23	35	33	33	39
Oregon	1	...	1	2	1	1	2
Pennsylvania	13	18	18	23	22	26	25
Rhode Island	17	19	22	22	21	26	24
South Carolina	1	1	...	1	2	4	1
South Dakota	1	1	1	1	...	...	...
Tennessee	1	2	3	5	3	4	1
Texas	...	1	2	...	1	2	5
Utah	...	...	...	...	...	...	1

States.	1886.	1887.	1888.	1889.	1890.	1891.	1892.
Vermont	3	7	5	4	4	5	4
Virginia	5	5	4	6	5	6	4
Washington	...	1	...	2	2	3	3
West Virginia	1	...	...	2	2	2	2
Wisconsin	3	5	7	9	10	7	9
Wyoming	...	...	1	...	...	....	....
Foreign Countries							
Argentine Rep.	...	...	...	...	2	....	....
Belgium	1	...	...	...	...	....	1
Brazil	...	1	2	2	2	4	....
Bulgaria	...	...	...	1	1	1	1
Central America	...	...	...	...	...	1	1
Colombia	...	...	...	1	...	2	....
England	...	...	...	...	2	1	1
France	...	...	...	1	1	1	1
Greece	...	...	1	...	...	....	....
Guatemala	...	1	1	1	...	....	1
Hawaiian Islands,	...	...	1	4	4	4	2
Holland	...	...	...	...	...	2	2
Ireland	...	1	1	1	1	....	....
Japan	1	1	...	1	4	3	1
Mexico	...	...	...	1	1	1	1
New Brunswick	1	...	1	1	1	2	1
New South Wales,	...	...	...	...	...	1	1
Nova Scotia	...	...	...	2	2	1	....
Peru	2	1	2	1	3	1	...
Porto Rico	...	1	2	2	2	1	....
Province Ontario	...	1	2	1	1	2	2
Province Quebec	3	2	1	1	4	4	5
Scotland	...	...	1	1	3	2	1
Spain	...	...	...	...	...	....	1
Trinidad	...	1	1	1	1	1	....
Turkey	...	1	1	2	1	2	1
Venezuela	...	...	...	...	...	1	....
Total	637	720	827	909	937	1,011	1,060

RESIDENCE OF MASSACHUSETTS STUDENTS.

It has been said that 56.9 per cent of our students are from Massachusetts. All the counties of the State, except the small counties of Dukes and Nantucket, send students to the Institute. One hundred and fourteen cities and towns are borne on the lists, four more than last year. The first column of the following table shows the number of cities and towns in each county sending pupils to the Institute; the second column gives the aggregate number

from each county. It appears that Suffolk and Middlesex send us 185 pupils each; Essex comes third, with 75; Norfolk fourth, with 72.

County.	No. of Towns.	No of Students.	County.	No. of Towns.	No. of Students.
Barnstable . . .	2	4	Hampshire . .	1	1
Berkshire . . .	2	4	Middlesex . .	32	185
Bristol	6	13	Norfolk . . .	19	72
Essex	18	75	Plymouth . . .	10	28
Franklin	3	3	Suffolk	4	185
Hampden . . .	4	15	Worcester . .	10	18
Total . . .	35	114	Total . . .	111	603

The following is a list of the towns, thirty-four in number, which send four or more scholars to the Institute: —

Boston	168	Malden . . .	9	Medford . . .	5
Newton . . .	31	Salem. . . .	9	Quincy. . . .	5
Brookline . . .	22	Framingham .	8	Wellesley . . .	5
Cambridge . .	22	Melrose . . .	8	Woburn . . .	5
Somerville . . .	16	Reading. . .	7	Concord . . .	4
Chelsea	15	Watertown . .	7	Gloucester . .	4
Lynn	13	Wakefield . .	6	Hingham . . .	4
Newburyport . .	13	Weymouth . .	6	Kingston . . .	4
Lowell	11	Taunton . .	5	Marlborough . .	4
Hyde Park . .	10	Andover . .	5	Needham . . .	4
Springfield . .	10	Arlington . .	5	Rockland . . .	4
Waltham . . .	10	Fitchburg . .	5		
Lawrence . . .	9	Haverhill . .	5		

PROPORTION OF OLD AND NEW STUDENTS.

The following table exhibits, for each year since 1883, the distribution of the total number of students among two classes: first, those students whose names are found upon the catalogue of the year preceding; and secondly, those students whose names appear as new names upon the catalogue of the year to which the statement relates: —

Year.	(1) Total No. of Students.	(2) No. of Students in the Catalogue of the previous year who remain in the Institute.	(3) No. of New Students entering before issue of Catalogue.	(4) Of those in column (3) the following number are regular first-year Students.	(5) No. of New Students, not of the regular first-year class.
1883–84	443	231	212	140	72
1884–85	579	311	268	186	82
1885–86	609	369	240	177	63
1886–87	637	379	258	190	68
1887–88	720	396	324	229	95
1888–89	827	465	362	245	117
1889–90	909	557	352	255	97
1890–91	937	572	365	234	131
1891–92	1,011	624	387	258	129
1892–93	1,060	618	442	303*	139

It appears from the foregoing that the number of students remaining over has been decreased by 6, while the number registered for the first time is larger by 55, making the total gain, as previously stated, 49.

AGES OF STUDENTS ON ENTRANCE.

The next table exhibits the ages of our students upon entrance. The regular students of the first-year class number 314. From these we should except 17 cases of students of unusual ages. These deductions leave 297 as the number of students whose ages have been made the subject of computation.

The results appear in the following table, in comparison with the corresponding results for 1891–92 : —

* In addition, 11 students are repeating the first year.

Period of Life.	1891–92.		1892–93.	
	Half-Year Groups.	Yearly Groups.	Half-Year Groups.	Yearly Groups.
16 to 16½ years	..	..	3	..
16½ to 17 years	4	4	5	8
17 to 17½ years	26	..	18	..
17½ to 18 years	39	65	36	54
18 to 18½ years	41	..	49	..
18½ to 19 years	50	91	55	104
19 to 19½ years	35	..	58	..
19½ to 20 years	21	56	32	90
20 to 20½ years	18	..	25	..
20½ to 21 years	8	26	7	32
21 to 22 years	9	9	9	9
	251	251	297	297

From the foregoing tables it appears that the average age of the 297 students taken for this comparison, the present year, is 18 years and 10 months.

In this connection it may be interesting to note the ages at graduation of the class leaving us in June. The 132 members of the class were distributed among the several periods of life as follows:—

Under 20	2	Between 22 and 23	46
Between 20 and 20½	2	" 23 and 24	24
" 20½ and 21	10	24 and over	12
" 21 and 21½	14		—
" 21½ and 22	22		132

PROPORTION OF REGULAR AND OF SPECIAL STUDENTS.

The following table exhibits both the absolute number of regular and of special students, as by the catalogue of each successive year since 1882, and the proportion existing between these two classes: —

Year.	No. of Regular Students.	No. of Special Students.	Total No. of Students.	Percentage.	
				Regular.	Special.
1882–83 . .	219	149	368	60	40
1883–84 . .	272	171	443	61	39
1884–85 . .	368	211	579	64	36
1885–86 . .	415	194	609	68	32
1886–87 . .	442	195	637	69	31
1887–88 . .	520	200	720	72	28
1888–89 . .	590	237	827	71	29
1889–90 . .	652	257	909	72	28
1890–91 . .	658	279	937	70	30
1891–92 . .	706	305	1,011	70	30
1892–93 . .	774	286	1,060	73	27

WOMEN AS STUDENTS IN THE INSTITUTE.

The number of women pursuing courses with us is 41. Of this number, 4 are graduates of colleges. Of the total number, 1 is a regular student of the fourth year; 5 of the third year; 3 of the second year; 4 of the first year. Twenty-eight are special students. Of the 9 regular students of the upper classes, 2 take Course IV., architecture; 2 Course V., chemistry; 1 Course VII., natural history; 3 Course VIII., physics; 1 Course XII., geology. Of the special students, 6 devote themselves to architecture; 3 to chemistry; 3 to physics; 11 chiefly to biology and allied subjects; 3 to English, history, or political science; 1 to geology, and 1 to mathematics.

GRADUATES OF OTHER COLLEGES.

Forty-nine graduates of institutions conferring degrees are included in our list of students for the present year. Of these, 6 are our own graduates, of whom 3 are pursuing studies as candidates for advanced degrees. Forty-three are graduates of other institutions pursuing courses of study with us, either as regular or as special students. Of these, 12 are graduates of Harvard University, 3 each of Amherst College, Smith College and Yale University, while 1 comes from each of the following institutions: University of Alabama, Boston University, Drake University, Johns Hopkins University, University of Minnesota, University of the

City of New York, Northwestern Universrty, Bowdoin College, Centre College, Iowa Agricultural College, Lafayette College, Maine State College, Marietta College, Middlebury College, Oberlin College, Ogden College, Robert College, St. John's College, Wellesley College, Michigan Mining School, National Institute, and Worcester Polytechnic Institute.

Of the 46, not candidates for advanced degrees here, 7 are regular students of the fourth year, — 3 in civil engineering, 4 in electrical engineering; 12 are regular students in the third year, — 1 in civil engineering, 3 in mechanical engineering, 4 in architecture, 1 in chemistry, 3 in electrical engineering; 5 are regular students in the second year, — 1 in mining engineering, and 4 in electrical engineering; the remaining 22 are special students.

Mr. J. A. Meyer, Jr., of the class of 1891, in architecture, Mr. F. E. Sanborn, of the class of 1889, in mechanlcal engineering, and Mr. P. A. Hopkins, of the last graduating class in architecture, are candidates for higher degrees. Mr. H. Gilmore, of the last class in mechanical engineering, has returned to take an additional year of study as a candidate for the bachelor's degree in electrical engineering. Mr. H. G. Dyar, of 1889, is taking special work in the Biological Department.

Messrs. H. B. Roberts, of 1890, and T. H. Skinner, of 1892, are continuing their studies here.

THE COURSES OF INSTRUCTION.

The following table presents the number of students in each of the regular courses of the second, third, and fourth years: —

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Electrical Engineering.	Biology.	Physics.	General Course.	Chemical Engineering.	Sanitary Engineering.	Geology.	Total.
4th Year Class .	27	33	6	6	8	40	2	..	6	8	..	2	138
3d " " .	23	29	5	14	13	30	3	4	5	15	3	..	144
2d " " .	26	44	8	17	14	42	4	1	5	11	2	1	175
Total . .	76	106	19	37	35	112	9	5	16	34	5	3	457

The following table shows the figures of the total line in the foregoing table, in comparison with the corresponding figures for the next eight preceding years: —

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Electrical Engineering.	Biology.	Physics.	General Course.	Chemical Engineering.	Sanitary Engineering.	Geology.	Total.
1884	29	54	28	9	20	30	1	1	3	..	..	..	175
1885	44	74	26	10	23	41	4	1	5	..	..	..	228
1886	45	75	19	13	24	52	4	2	8	..	..	..	242
1887	50	89	16	18	23	61	5	6	14	..	..	..	282
1888	71	100	12	21	28	74	4	5	12	11	..	..	338
1889	79	99	14	30	29	91	9	5	12	14	6	..	388
1890	79	95	18	27	27	105	11	4	13	18	7	3	407
1891	81	104	17	33	23	108	11	5	19	28	9	3	441
1892	76	106	19	37	35	112	9	5	16	34	5	3	457

It will appear from the foregoing table that the course in Electrical Engineering remains, as it has been for three years, the largest of the courses of the School. The courses in Mechanical and in Civil Engineering follow, in the order in which I name them. These three courses together comprise about two thirds of our regular students, candidates for the degree of the Institute. In the case of Course IV., the number of regular students fails to measure the importance of the department to the School, inasmuch as that course embraces a considerable number of college graduates and of young men who have had experience as draughtsmen and assistants in architects' offices, who are allowed to enter the department as special students, to get as nearly as possible what they require, without passing through the full course. Thus, the number of special students in Architecture the present year is sixty-one, which, added to the thirty-seven regular students, makes the total number ninety-eight. The Chemical and Biological courses also contain considerable numbers of special students, often of advanced grade, some of them teachers or persons who have been engaged in professional practice. In regard to the courses appearing as having a very small number of students, it should be said that the figures do not fairly represent the importance of these courses to the Institute. Thus, the Physics course, being a pure science course, has never had, and is not expected to have, a large number of students. Such

a result is not even desired by the Faculty. Yet that course has been a power for good in the Institute; some of our strongest students have graduated from it; and the influence of the instruction given in it and of the men taking it has always had a great effect upon the technical courses of the School.

The following table exhibits the number of persons who have graduated within each of the several courses, at each succeeding year since the first diplomas were conferred: —

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering.	Architecture.	Chemistry.	Metallurgy.	Electrical Engineering.	Natural History or Biology.	Physics.	General Course.	Chemical Engineering.	Sanitary Engineering.	Geology.	Total.
1868	6	1	6	..	..	..	..	..	..	1	..	..	..	14
1869	2	2	..	..	1	..	..	..	..	..	..	..	..	5
1870	4	2	2	..	1	..	..	..	..	1	..	..	..	10
1871	8	2	5	..	2	..	..	..	..	..	..	..	..	17
1872	3	1	5	..	3	..	..	..	..	..	..	..	..	12
1873	12	2	3	1	7	..	..	..	..	1	..	..	..	26
1874	10	4	1	1	..	..	..	..	..	2	..	..	..	18
1875	10	6	6	1	1	..	..	..	1	2	..	..	..	27
1876	12	9	7	..	5	1	..	2	3	4	..	..	..	43
1877	12	6	8	4	2	..	..	..	..	..	..	..	..	32
1878	8	2	2	3	3	..	..	..	..	1	..	..	..	19
1879	6	8	3	1	3	..	..	1	1	..	..	..	..	23
1880	3	..	3	..	1	..	..	..	..	1	..	..	..	8
1881	3	5	6	3	8	..	..	1	..	2	..	..	..	28
1882	2	5	5	3	6	..	..	1	1	1	..	..	..	24
1883	3	7	5	1	3	..	..	..	..	..	..	..	..	19
1884	5	6	13	..	12	..	..	..	..	..	..	..	..	36
1885	4	6	8	2	4	..	2	..	..	1	..	..	..	27
1886	9	23	7	1	7	..	10	1	..	1	..	..	..	59
1887	10	17	8	1	9	..	8	1	1	3	..	..	..	58
1888	11	25	4	5	10	..	17	3	1	1	..	..	..	77
1889	15	23	5	3	8	..	17	1	1	2	..	..	..	75
1890	25	27	3	5	13	..	18	3	2	6	..	..	..	102
1891	17	26	4	6	11	..	23	3	3	1	7	..	1	102
1892	22	26	4	12	7	..	36	6	1	7	4	6	1	132
Total,	222	241	123	53	127	1	131	23	15	38	11	6	2	993
Deduct names counted twice														4
Net total														989

Our special students, of course, cannot be classified systematically; but the following table exhibits the number of such students pursuing each particular branch of study: —

NUMBER OF SPECIAL STUDENTS ATTENDING EXERCISES IN THE FOLLOWING DEPARTMENTS OF STUDY OR PRACTICE.

Applied Mechanics	54	History	50
Architecture	61	Language	146
Biology	28	Mathematics	163
Chemistry	84	Mechanical Engineering	68
Civil Engineering	27	Mining Engineering	8
Drawing	163	Physics	142
Electrical Engineering	18	Political Science	32
Geology	33	Shop-work	68

It may be of interest to note the number of students, either regular or special, pursuing certain leading branches of study, in each of the four years, as follows: —

Studies.	First Year.	Second Year.	Third Year.	Fourth Year.	Total.
Mathematics	367	239	158	51	815
Chemistry	386	63	48	31	528
English	341	219	16	9	585
French	249	141	42	9	441
Physics	...	265	190	124	579
German	62	181	132	4	379
Shop-work	14	114	47	45	220

The number of students in the five-year courses is 50, against 41 last year. The following table shows the distribution of this total by years and by courses: —

FIVE-YEAR COURSES.

Year.	Total.	Course.										Course Undetermined.
		I.	II.	III.	IV.	VI.	VII.	IX.	X.	XI.	XII.	
First	7	..	..	..	..	..	..	..	..	..	..	7
Second	19	1	8	1	4	4	..	..	..	..	1	..
Third	13	3	1	..	3	1	1	1	2	1	..	..
Fourth	7	..	3	..	3	1	..	..	..	..	..	..
Fifth	4	1	2	..	..	..	..	..	1	..	..	..
	50	5	14	1	10	6	1	1	3	1	1	7

CHANGES IN BUILDINGS AND ROOMS.

The Department of Architecture having entirely outgrown its previous quarters, the Corporation have this year erected a new building to be wholly devoted to it. This building has been carefully planned to meet the needs of instruction, and is fitted with every material appliance required for the fullest and best professional and technical training. It measures 66 feet by 58, and has a basement and five stories.

One half of the basement is a museum for building appliances; the other half is a laboratory for the testing of cements, mortars, etc., and has also a complete plant for experimenting on the siphonage of plumbing traps. This system is arranged to be in exact accordance with the plumbing practice in private houses, in order that the experiments may be thoroughly practical and useful.

The first floor is devoted to lecture rooms. The second and fourth floors are large drawing rooms, lighted from both sides. One half of the third floor is a drawing room, the other half contains the library. The library is very fully equipped and catalogued, and has every convenience for ready consultation of its eight hundred volumes and ten thousand photographs. The fifth and upper story constitutes one large drawing room, arranged for the classes in freehand drawing from the cast and from life, and for the classes in water color and modelling. The lighting of this room has had the most careful study, and its arrangement of skylights and sidelights is unsurpassed. The heating and ventilating apparatus of the building is so planned that the rooms are kept at a constant regular temperature by means of electrical appliances, and the air is constantly changed without the necessity of an open window. This noble and commodious building has been erected on the land immediately south of the Engineering Building, and in form constitutes an extension of the front of that building, with which it immediately connects and with which it communicates on each floor.

The removal of the Department of Architecture from the Walker Building to its new home gave room for a much-needed expansion

of the departments of Chemistry and Physics. The space thus left vacant was given entire to these departments, except that a single suite of rooms on the second floor was reserved for modern language recitation rooms. This occasion was taken for a considerable rearrangement, as well as enlargement, of both departments. These changes in the use of the Walker Building are so intimately connected with the increasing specialization of the work of instruction and research, that I shall describe them in detail while speaking, a little later, of the changes and developments of the year in Courses V., VI. and VIII. Suffice it to say here that the gain has been very great; greater than would appear probable from the mere extent of additional space acquired. We have been enabled to undertake work from which we have heretofore been debarred by the lack of just these facilities, while other work which we have previously undertaken we are now able for the first time to do to our entire satisfaction. The influence upon both the outgoing department of Architecture and the remaining departments of Chemistry and Physics, due to the enjoyment of something like adequate space, has suggested to our minds the daring speculation, what if the Institute of Technology were to have all the room it needed, and were to be in possession of the material means for doing all the good it is qualified and prepared to do! The subject is too vast for treatment, and I drop it here with the bare suggestion.

In the Engineering Building the only notable change of the year has been the painting in white of the larger part of the interior, adding greatly to the light available for work in the drawing rooms and laboratories during the short winter afternoons.

THE LIBRARY.

The report of the librarian, Mr. C. W. Andrews, contains the following statistics: —

The total accessions for the year have been 4,254, of which 1,470 have been received as gifts or in exchange; 2,354 obtained by purchase; 430 by binding periodicals and pamphlets. The net accessions have been 4,107, of which 3,320 are volumes and 787 pamphlets. The distribution and cost, including binding, of the accessions and the total number of volumes in each department library are shown in the following table: —

Library.	Vols. added.	Pphs. added.	Cost.	Pamphlets (bound and unbound) already catalogued.	Total No. of vols.
General	311	213	$178 41	1,772	2,619
Engineering	510	115	1,020 00	964	3,783
Mining	149	30	189 12	147	1,165
Architectural	142	3	453 40	5	950*
Chemical	398	105	748 49	951	5,061
Biological	126	82	164 99	183	1,259
Physical	314	31	659 53	232	3,304
Political Science . . .	756	194	698 07	1,766	5,151
English	439	2	321 34	31	1,496
Geological	145	12	131 51	48	1,300*
Margaret Cheney Room,	30	0	.....	8	543
Total	3,320	787	$4,564 86	6,107	26,631

The total number of pamphlets is unknown, but it certainly exceeds ten thousand.

The total number of periodicals received, excluding annuals, is 373. Of these, 229 were subscribed for at a cost of $1,188.24; 69 were received in exchange, and 75 as gifts. The number of duplicate copies received is 16, and the number of separate periodicals, 362. The distribution of these periodicals is shown in the following table: —

Library.	By Subscription.	Total.	Cost.
General	10	32	$34 36
Engineering	36	83	223 15
Mining	16	19	81 50
Architectural	14	17	94 75
Chemical	35	58	206 80
Biological	26	30	155 50
Physical	20	34	123 00
Political Science and English .	64	87	242 68
Geological	2	7	14 50
Lowell School of Design . .	6	6	12 00
Total	229	373	$1,188 24

* The numbers marked with an asterisk are only approximate, as these libraries have not yet been catalogued.

During the year 5,787 cards have been added to the main catalogue, which now contains 23,107 cards, covering 25,029 volumes and 6,107 pamphlets. The Engineering Library and that of the Margaret Cheney Room have been catalogued.

While as many gifts of single books have been received as in previous years, there has been but one gift of a considerable number, viz., 34 volumes on chemistry from Dr. B. S. Shaw, of Boston. The purchase of books on highway engineering, from the Pope Fund, has been continued.

THE CORPS OF INSTRUCTORS.

The catalogue of 1892-93 shows the number of instructors of all grades to be 109, inclusive of those concerned with the mechanic arts, but exclusive of those who are announced as lecturers for the year only. The addition of these would raise the total to 125, made up as follows: —

Professors	16
Associate Professors	11
Assistant Professors	11
Instructors	41
Assistants	30
Lecturers for the year	16
	125

The following table shows the gain or loss in the several classes during the year: —

	1891–2.	1892–3.
Professors	12	16
Associate Professors	13	11
Assistant Professors	8	11
Instructors	42	41
Assistants	27	30
Lecturers	18	16
	120	125

The instructing staff for 1892–3 is distributed as follows among the several departments of the School.

	Civil Engineering.	Mechanical Eng. and App. Mechanics.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Physics and Electrical Engineering.	Biology, Zoölogy, etc.	Mineralogy, Geology, and Geography.	English, History, and Political Science.	Language.	Mathematics.	Drawing and Descriptive Geometry.	Mechanic Arts.	Military Tactics.
Professors . . . . (16)	1	1	1	2	2	1	1	1	2	1	2	..	..	1
Associate Professors . (11)	3	2	1	..	1	1	..	..	1	..	2	..	..	..
Assistant Professors . (11)	..	3	..	1	2	..	..	1	..	2	1	1	..	..
Instructors . . . . (41)	3	2	1	1	8	6	1	1	3	2	6	4	3	..
Assistants . . . . (30)	3	10	..	1	7	2	2	..	..	..	..	2	3	..
Total . . . . (109)	10	18	3	5	20	10	4	3	6	5	11	7	6	1
Lecturers . . . . (16)	1	..	1	4	2	4	2	..	1	1	..	..	..	..
Total . . . . (125)	11	18	4	9	22	15	6	3	7	6	11	7	6	1

These tables show that, with 1,060 pupils, we have one instructor to 10 pupils, if the lecturers for the year be excluded from the account; one instructor to eight and a half pupils, if the lecturers be included. Either mode of computation shows a very large proportion of instructors, made necessary both by the nature of much of the work pursued in the school, where only a small group of pupils can work with an instructor over a machine, or around a bench or desk, and by the highly specialized instruction given in the later years which tends to form in some cases extremely small sections.

CHANGES IN THE FACULTY AND THE CORPS OF INSTRUCTORS.

The changes in the faculty and the corps of instructors, during the year, have been more important than those which have occurred in any previous year since I assumed the duties of President. Some of these changes are more deeply to be regretted than it would be possible to express in words. Two professors of the highest eminence have been lost to the faculty of the Institute; one by resignation, the other by death.

M. Jules Luquiens came to the Institute in 1874 as instructor in modern languages; in 1880 he was promoted to be Assistant Professor; in 1884, to be Associate Professor; while in 1892 he was advanced to a full professorship, which he has resigned to accept the professorship of the Romance Languages in Yale University. Prof. Luquiens's superb scholarship will find a far wider field at New Haven than could be afforded it in the elementary instruction to which he was necessarily confined here; but he cannot be more highly esteemed and appreciated there than he was by the faculty and the students of the Institute of Technology. Eminently and in every sense a scholar, he was also a most successful teacher. If I were to select one quality out of the many which made him so useful and so honored in his service with us, it would be his conscientiousness in the discharge of every duty. It was impossible for him to slight any part of the work which devolved upon him, however tedious, however seemingly insignificant. Prof. Luquiens has carried with him to his new field of labor the gratitude and affection of all his former associates and of a host of "Institute men."

M. Jean Eugène Létang came to this country and to the Institute of Technology in 1871. One of the most brilliant of the pupils of the Ecole des Beaux Arts, the traditions of whose accomplishments still linger in that greatest school of art, he had been selected as Prof. William R. Ware's assistant in architectural design. It was necessarily a venture fraught with uncertainty to bring such a man hither; but the result has been a great uplifting of architecture in the United States. Hundreds of his pupils are now leading architectural practice in the great cities of our country. Shy, incapable of or altogether averse to lecturing, his chosen field was the drawing room, where, bending over each student in succession, he brought into play his rare powers of criticism, correction, and instruction. Returning to Boston after a summer abroad, he resumed his duties for the current year, only to be stricken down by disease which terminated fatally on the 28th of November. He has died, lamented by hundreds of pupils who will never cease to feel that to him they owe the inspiration which has given life to their professional careers. To fill his place in the Institute is a problem of the greatest difficulty and nicety, to which Prof. Chandler and the Executive Committee are giving the most earnest attention.

During Prof. Létang's sickness of six weeks, his classes were taken by Mr. Samuel W. Mead, of the firm of Cabot, Everett & Mead, architects, of this city. Mr. Mead, one of the earliest recipients of the Rotch scholarship, has been well trained in classical studies, and is in full sympathy with the thorough, thoughtful, academic spirit which has characterized the drawing-room work of the Institute under Prof. Létang. Mr. Mead will remain in charge of this department for the remainder of the year.

The Chemical Department of the Institute has been immensely strengthened for the current year by the consent of Prof. Crafts to assume, for that period of time, the charge of the instruction and laboratory work in organic chemistry. Such a re-enforcement is far beyond anything we had a right to expect, and has given strength and inspiration, not to the department alone, but to the whole school. Dr. Arthur A. Noyes, for several years instructor in analytical chemistry, has been appointed instructor in organic chemistry, to conduct the laboratory work under Prof. Crafts's direction, relieving Mr. Clement W. Andrews, to enable that very efficient officer to devote more time to the library of the Institute.

Dr. Thomas Evans, a graduate of the University of Erlangen, has been appointed an assistant in this department.

Ever since the foundation of the Institute, instruction in military tactics has been given in the school, as provided by the act of Congress of July 2, 1862, under which we receive a portion of our annual income. The requirement of military instruction has always been honestly dealt with here, a substantial course being given, without interruption, to the students of the first year. During the summer of 1891, the Executive Committee of the Corporation determined that it was best, in view of the large number of students in the first year, that the instruction in military tactics should hereafter be given by an officer of the United States Army as contemplated, although not required, by the act of 1862. They accordingly addressed the Honorable Secretary of War with a request for the detail of an officer for this service. Some delay occurred in making the detail, but in February, 1892, Lieut. Harry L. Hawthorne, of the 4th Artillery, was assigned for this service. Lieut. Hawthorne reported a little later, relieving in this duty Gen.

Hobart Moore, who had for many years given the instruction in this department with the greatest care, pains, and effort, and with all the success which it was reasonable to expect under civilian management.

Lieut. Hawthorne entered the Naval Academy at Annapolis in 1878, graduating in 1882. He was on sea service until June, 1884, when he passed his final examinations for appointment as an officer of the navy. The navy at that time affording opportunity for commissioning but a small part of the graduates of the Academy, he was honorably discharged from the service under the act of Congress, approved Aug. 5, 1882. Passing examinations at once for the military service, he was commissioned second lieutenant of the 2d Artillery in October of 1884. He took part in the operations against the Sioux Indians in the winter of 1890–91, and commanded the artillery in the fight at Wounded Knee Creek, Dec. 9, 1890, where he was severely wounded. For gallantry and ability displayed on this occasion, he was recommended for brevets of first lieutenant and captain; was mentioned in General Orders from the Headquarters of the army; and was presented with a medal by Congress. He received his commission as first lieutenant, Aug. 28, 1891.

Lieut. Hawthorne entered upon his duties, with the rank of Professor in the Faculty, about the middle of March; and took up the problem of instruction in military tactics in a school of this character, — for the problem must necessarily vary greatly with the varying character of schools, — with much intelligence, spirit, and activity. I cordially invite the attention of all members of the Corporation to this feature of the Institute, confident that they would be deeply interested by a visit to the school for this purpose alone. By a favor which cannot be too highly appreciated, and for which Gen. Dalton and his Excellency Gov. Russell have our hearty thanks, the battalion is allowed to drill three times a week, namely, Tuesday, Thursday, and Saturday mornings, from nine to ten o'clock, in the State Armory on Irvington Street. The list of instructors in military tactics from the beginning has been as follows : —

1868–1872, Gen. Hobart Moore, Instructor.
1871–1876, Lieut. E. L. Zalinski, U. S. A., Professor.
1876–1878, Lieut. H. W. Hubbell, Professor.
1878–1879, Lieut. Robt. W. Carter, U. S. A. (retired), Instructor.
1880–1883, Col. John C. Chadwick, Instructor.
1883–1892, Gen. Hobart Moore, Instructor.

The other changes in the Faculty have been: —

The promotion of Associate Professors Dewey and Levermore to be Professors of Economics and Statistics and of History, respectively.

Of Assistant Professor H. W. Tyler to be Associate Professor of Mathematics.

Of Instructors, Henry P. Talbot, Dana P. Bartlett, Edward F. Miller, and Frank Vogel to be Assistant Professors of Analytical Chemistry, Mathematics, Steam Engineering, and Modern Languages, respectively.

Still another change has been wrought by death in the instructing staff of the Institute. On the 14th of August, Mr. George V. McLauthlin, instructor in biology, was drowned at Nahant, while bathing off the shore. Mr. McLauthlin, a native of East Bridgewater, Mass., graduated from the course in Chemistry with the class of 1888. After engaging in practical chemical work for two years, he was in 1890 appointed assistant in biology, and in May last was promoted to be instructor, with reference to the coming year. From his entrance into the biological laboratory he displayed extraordinary ability as an investigator and as a teacher, and at the time of his death was regarded as one of the rising men of the Institute of Technology. His industry was remarkable, his insight quick and keen; while his attachment to his chosen profession was earnest and entire. For the State Board of Health, under the direction of Prof. Sedgwick, Mr. McLauthlin made several important investigations. In particular may be mentioned his careful study of the local conditions of the public spring waters sold in Massachusetts, of which a report is now issuing from the press, and an inquiry into the causes of the excess of typhoid fever in certain cities of the State. At the time of his death he had completed a special report to the State Board of Health upon an outbreak of typhoid fever in Chicopee Falls, which he traced and proved to be due to the use of

infected drinking water. A full account of this investigation will appear in the report of the Board for 1892.

In the Mathematical Department two new instructors were appointed for the current year; one to fill the vacancy caused by the assignment of Dr. Tyler to the secretaryship of the Institute, the other with a view to increasing the number of sections for the purpose of embracing fewer students in a section. The gentlemen appointed were Mr. Leonard M. Passano, A. B., of the class of 1889, Johns Hopkins University, and Mr. William H. Metzler, A. B., of Toronto University, both of whom have had valuable experience in teaching before coming to the Institute.

The proposed increase in the number of mathematical sections was effected as follows: in the third year from eight to nine; in the second year from ten to twelve; in the first year from sixteen to eighteen. This increase of sections called for seventeen hours more of class-room exercises per week in the first term, and of fourteen hours more in the second term. But, while the proposed increase of sections was duly carried out, no general reduction in the size of the sections has resulted. This negative result is due to the increase of the classes. In the first year the effects of the increase in the number of sections was more than offset by the great gain in the number of students. It is much to be hoped that the financial means of the Institute will, another year, be such as to allow still further additions to the instructing staff in mathematics. Mr. Frederick S. Woods of this department is still absent, pursuing advanced studies in the University of Göttingen, Germany.

Considerable attention has been given to the formation and arrangement of a special mathematical library, and a number of English and American text-books have been secured to supplement the mathematical instruction in elementary branches as well as more advanced treatises in English, French, and German. The department hopes to secure during the present year a representative collection of mathematical models.

The Annual Catalogue for the current year contains an announcement of an important increase in the requirements in mathematics for admission. Beginning with the examinations of June, 1894, candidates will be required to present either the portions of

algebra now included in the first-year course or, at their choice, solid geometry. The announcement is accompanied by a statement that the Faculty hope to see their way, at no distant date, to embrace both these requirements in the conditions of admission. The step already taken cannot fail to have an important effect upon the future rearrangement of the mathematical courses of the school, and upon the relation of our mathematical work to the technical instruction given in the several engineering courses.

In the department of Modern Languages two new appointments were made with reference to the present year. Unfortunately both were to fill vacancies, those, namely, caused by the resignations of Prof. Luquiens and Mr. Heller. It is much to be regretted that the means of the Institute did not permit the appointment of one or even two additional instructors in modern languages. Such action cannot long be delayed. The existing staff are laboring hard to carry the weight imposed upon them by a considerable increase of students, over the large numbers of last year. In addition to the two appointments referred to, however, some relief has been obtained by giving the class in Spanish to Mr. Johann Meyer for the present year.

The Instructors appointed as above were Mr. Ch. H. L. N. Bernard, from the High School of Oswego, and Mr. Joseph Blachstein, who has for some years been engaged in giving private instruction in Boston.

It is believed that the larger requirements in French (or German) for admission adopted last year will soon yield valuable fruit in better work at the Institute. The Faculty are also favorably disposed towards a still further increase in these requirements at no distant date. Such a school as this ought to receive only pupils who can read ordinary French and German works fluently and correctly, so that the instruction in the Institute itself may be reserved for higher study of these languages and the acquisition of a complete mastery of technical vocabularies. Towards that desirable end we already see progress making through the efforts of the Association of New England Colleges.

The assignment of a suite of rooms on the second floor of the Walker Building to the Modern Language Department, heretofore

mentioned, has been found of great benefit. The teachers in this department are thus brought nearer together, affording opportunities for easy consultation regarding the progress of different sections of the same class, or regarding students requiring particular attention. Moreover, a common room for the teachers in the department has been provided, where all can meet and each can keep his records and other papers. It is much to be regretted that several other rooms are not available for similar purposes in the various buildings of the Institute.

Of the Instructors of last year, the following have resigned: —

Mr. Arthur L. Williston, Mechanical Engineering.
Mr. Edward V. French, " "
Dr. Edward G. Gardiner, Biology.
Mr. Collier Cobb, Geology.
Mr. Otto Heller, Modern Languages.

Messrs. Williston and French have engaged in professional practice; Mr. Heller has become Assistant Professor in Washington University; Mr. Collier Cobb, Assistant Professor in the University of North Carolina.

To fill the vacancy caused by Dr. Gardiner's resignation, Mr. Richard E. Edes has been appointed Instructor in Biology. Mr. Edes graduated from the biological department of Johns Hopkins University in 1889.

Mr. Edward Robinson, of the class of 1890, has been appointed Instructor in Mechanical Drawing.

The following named gentlemen, Assistants last year, have been promoted to be Instructors, viz.: —

Harry M. Goodwin, in Physics.
William Lincoln Smith, in Physics.
Hamilton Rice, in Drawing and Descriptive Geometry.

Mr. Goodwin, at the time of his promotion, was granted leave of absence to enable him to pursue advanced studies in Physics in Germany. He is now at the University of Leipsic. It is hoped that this brilliant young scholar will return to continue his work of instruction at the Institute.

The appointments of two Instructors in Mathematics and of two

in Modern Languages have been mentioned in connection with the remarks on the instruction in those departments.

The list of Assistants for the current year is as follows: in Civil Engineering, Nathan R. Pratt, Joseph P. Lyon, Macy S. Pope. In Mechanical Engineering and Applied Mechanics: Carleton A. Read, James Swan, Fred A. Wilson, Phillips P. Bourne, Charles E. Fuller, William A. Johnston, Walter M. Newkirk, Charles F. Park, Dwight P. Robinson, Edward C. Wells. In Architecture: Robert S. Shedd. In Chemistry: Willis R. Whitney, Oscar W. Pickering, L. Kimball Russell, G. Russell Lincoln, Thomas Evans, Jesse F. Johnson, Herbert R. Moody. In Physics and Electrical Engineering: Louis Derr, George V. Wendell. In Biology: Severance Burrage, Albert P. Mathews. In Drawing and Descriptive Geometry: O. W. McD. Cushing, Walter B. Trowbridge. In the Mechanic Arts: James D. Littlefield, Clarence M. Brockway, Charles L. Conant.

THE EARLIER CHOICE OF COURSES.

A very important change in the policy of the school has been the adoption of the rule that students shall make their choice of courses at the opening of the second term, instead of at the opening of the second year, as heretofore. This rule takes effect at once. The Faculty have long desired to bring this about, but not until now have they seen their way to effect it. The advantages looked for from this change are as follows: —

(1.) The students will come earlier under department supervision. Each student will, from the close of the first term, belong to a department, to the head of which he may resort for advice or needed assistance. The heads of departments, on the other hand, will begin looking after their own men one term earlier.

(2.) The interest of the student in the school and in his own work will be increased as he feels himself a member of a distinct course and sees himself ranked as such, instead of being merely one individual in a great unclassified body of students.

(3.) The long novitiate of the first year will now be abridged one half, and the students will earlier get a taste of professional study, although the main part of their work will necessarily still be

of a preparatory character. This last result cannot be avoided until the Institute is able largely to increase the requirements for admission.

(4.) There will be a better adaptation of the studies of the second term to the subsequent work of each student. For example, heretofore it has been necessary to extend one and the same chemical course throughout the first year. Those who were, in the result, to go into an engineering course, or into architecture, have been obliged to take a somewhat longer and a somewhat different course than would have been given them in the interest of general training, or with reference to their subsequent studies. Men, on the other hand, who were in the result to enter some chemical course, such as chemistry, metallurgy, biology, or geology, have been given a somewhat shorter and a somewhat different course than might have been thought desirable. In other words, the chemical work of the second half of the first year has thus far been in the nature of a compromise, precisely meeting the needs of neither the "chemical courses" on the one hand, nor the "mathematical courses" on the other. Under the new arrangement, the chemical work of this term will be adapted to the requirements of each group of students. The architectural students will drop chemistry entirely at the close of the first half-year, putting the time thus saved to use in drawing. The students of the course in General Studies take physical laboratory work the second half-year in place of chemistry, securing thus, it is believed, a more varied training in experimentation and observation.

The change fixing the choice of courses at the middle of the first year has enabled the Faculty to change the instruction in first-year drawing and descriptive geometry in several important particulars.

First, heretofore the sections of the class have been so large that most of the work has been done in the drawing room, and very little in the class room. In future the class will be divided into small sections, so that each student can have a fair share of the instructor's attention, and the student will receive the benefit of a class-room drill to teach him the principles underlying any special plate before he proceeds to draw it.

Second, inasmuch as the students of the separate courses are in separate sections, instruction is now to be adapted to the needs of each course. Thus, for the students of Courses V., VIII., XII., and the fourth option of Course III., the course in drawing and descriptive geometry will be substantially the same as before. For Course II., the first three options of Course III., and for Courses I., II., VI., X., and XI., the study of descriptive geometry will begin at the middle of the first year, and the student will thus become familiarized earlier than heretofore with the principles of the subject, and will be taught from the first to make drawings in all four angles, instead of confining him to the first angle. In this way, he will be better fitted for the kind of drawing which a mechanical engineer has to perform, and be better prepared for his professional work in the second year. For Course IV., a larger amount of time is given to drawing in the first year, thus enabling the student to complete the study of descriptive geometry in that year. Much more time will be given to the architectural students in free-hand drawing. For Courses VII. and IX., the descriptive geometry is to be omitted, chart and map making being substituted for it in the latter.

PRINTED NOTES FOR STUDENTS' USE.

One of the most difficult problems in a school of such aims as those of the Institute of Technology is that which relates to the text-books to be used by the students. In the earlier years of the course, and in departments like those of mathematics, language, and political science, suitable text-books can be procured; but much of the matter of technical instruction which is given here is not found in books at all; or, if found there, is already antiquated through the progress of experiment and research. In such lines, the best available books must be supplemented at great inconvenience by a wealth of material from current scientific journals and the proceedings of learned societies and engineering institutes. Even these will not suffice for all the purposes of a school which aims to lead engineering practice, and in whose laboratories absolutely new work is continually in progress. For a long time we felt ourselves too poor to deal with the subject as was to be desired; and the best

books to be obtained, often painfully backward and deficient, were supplemented, as far as might be, by "hectograph" notes, tables, and diagrams, sometimes difficult to be deciphered and trying to the eyes and the patience of the students. About 1886, however, the Executive Committee authorized the printing of small bodies of the most urgently needed notes, with lithographic or heliotyped illustrations. The advantages resulting from the use of the new pamphlets were so conspicuous that the practice rapidly extended, the notes being sold to the students at prices which were estimated sooner or later to repay the cost of printing and engraving. The following table shows the growth of this system, whose results have been inexpressibly beneficial to the several departments of instruction: —

	Receipts.		Expenditures.
1888 . .	$1,552 32	1888 . .	$1,772 30
1889 . .	1,799 63	1889 . .	1,657 62
1890 . .	1,662 69	1890 . .	1,861 38
1891 . .	2,176 00	1891 . .	2,401 21
1892 . .	2,339 95	1892 . .	2,522 23
	$9,530 59		$10,214 74

The notes thus printed for students are in editions calculated to last, in general, three years. At the end of that time, it is considered that a new issue, containing modifications and additions, to bring the notes up to date, will be necessary. Often at the end of the first or second year extensive interlineations or supplementary pages are required.

A rough count made of the different books and pamphlets of such origin now in the hands of our students, omitting all mere tracts of a few pages, and all series of engraved plates not bound up, shows the number to be forty, with an aggregate of 3,759 pages, 475 plates, and fully twelve hundred illustrations.

So far has this been carried, that the text-books in use at the Institute may largely be said to be of our own making. The gain to the efficiency of instruction and to the convenience of the students has been very great, with an actual saving in expenditure to the latter. Indeed, it may be said that in some departments we could not give the courses we do without this aid. In addition to

the foregoing, scores of books prepared by our own teachers and published in the usual way are in use in the school.

SUMMER SCHOOLS.

The Summer School in Topography, Geodesy, and Geology. — This school was again held, during the past summer, at the Delaware Water Gap during four weeks in June. In the absence of Profs. Burton and Niles, it was conducted by Prof. Porter, Prof. Crosby also being present during part of the time, and Messrs. Robbins and Verges assisting throughout the work. Sixteen students were in attendance. The ground covered by the plane table work adjoined that surveyed the previous year, extending for half a mile farther inland from the river and on to the hilly ground. We now have a map of between one and two square miles of area, minutely portraying the topographical and other details, and of special value in studying certain geological features of the locality.

Repeated measurements were made of a base-line some 2,000 feet long, using suspended metallic tapes and specially designed apparatus for regulating the tension. Experiments were also carried on with brass and steel tapes suspended side by side for determining the actual temperature of the tape, the coefficients of expansion having previously been accurately determined by experiments in the laboratory, by means of special apparatus designed under the direction of Prof. Burton. The heights of various prominent points were determined by barometric measurements, using both mercurial and aneroid barometers. Attention was also given to the solar attachment and to range finders and other instruments. The geological work embraced, as usual, a general study of the geology of the surrounding country in its relations to the topographic features, but especial attention was given to the construction of an accurate geological section about two miles long across the Kittatinny Mountain and Kemmersville anticline to Cherry Creek. The bearing of such a section upon practical engineering was made apparent to the students by doing the work substantially as if it had been proposed to locate a tunnel along the line of the section, the extent and character of each stratum which such a tunnel would

penetrate being determined. Excursions were also made to the Bangor slate quarries, to the great terminal moraine, and to various localities of paleontological interest.

The hydraulic work embraced a series of measurements of the volume of the Delaware River, made at three different gauging stations, so chosen as to give practice both in moderate and in swift currents. The measurements were made with sub-surface floats, as well as with the Ellis and the Fteley current meters. The observations there made have been worked up in the drawing room during the present term. The last two days of the course were devoted to a trip up the Lehigh Valley, stopping at Bethlehem, where special courtesies were extended by officials of the Bethlehem Steel and Iron Works, and at Mauch Chunk, where visits of inspection were made to mines, canals, the gravity railroad, and other engineering works.

Summer School of Mining. — This year the Summer School of Mining was held at Drifton, Penn., at the collieries of Coxe Brothers & Co. The students spent a month in making surveys below and above ground, as well as in making a special study of the methods of mining, moving, cleaning, and shipping the anthracite in preparation for the market. The collieries are among the finest in the country, both as to equipment and management. A warm welcome was given the students by Mr. Eckley B. Coxe, who not only opened the various departments freely to them, but delivered lectures upon the latest theories of colliery management, making this summer an important factor in the education of these young engineers. The Summer School was in charge of Profs. Richards and Hofman.

Summer Field Work in Mineralogy. — This was held in July, one week being spent by Prof. Crosby with sixteen students in visiting the noted localities in Paris, Me., and the adjoining towns. The students became greatly interested in the work, and the session, although brief, was in every way successful and satisfactory.

Courses I. and XI. Civil and Sanitary Engineering.

The course of study in civil engineering has been altered only in regard to a few minor matters. The staff of professors and instructors is the same as last year, except that two new assistants take the place of two retiring ones. Both of the new assistants were enabled, through the efforts of the department, to spend last summer in practical professional work with special reference to their duties here.

The graduates of the year in civil and sanitary engineering, as usual, obtained positions without difficulty; the number of applications received by the department has largely exceeded the number of men available. There has this year been an especially great demand for teachers of civil engineering. Since the close of last year, applications have been received for eleven teachers of civil engineering, several of these applications being from schools of high standing; yet only one could be filled. Two graduates from the Civil Engineering Department are now instructors in Cornell University, namely, Mr. Sherman, 1890, and Mr. Mott, 1889. Another graduate of this department, Mr. Brownell, 1890, was this year appointed instructor in civil engineering in Brown University.

The foregoing leads me to say that it is to be regretted that so few of our graduates, in all departments, are disposed to teach. That indisposition comes chiefly from the strong proclivity towards professional practice which is created by the large amount of experimental and practical work, which, at the Institute, is, from the first and all through our courses, associated with the theoretical instruction and the text-book exercises. Instead of shrinking back from the labor and responsibilities of practice, after four years of student life, our graduates are eager to go to work, and like nothing so well as to take hold at once of practical problems. This is good. It is, indeed, a characteristic feature of the school which we would not willingly lose. Yet, with the large and rapidly growing demand for teachers of physics, chemistry, and natural history in the secondary schools of the country, and with the not infrequent calls made upon us for men to become professors of engineering in the new technical schools now arising in all parts of the country, or in the older universities which are establishing technical departments, it would be a fortunate thing if, without impairing the promptitude and resolution with which the average graduate of the Institute takes hold of his professional work, we could find in each graduating class a small number, and those of the very best, who were willing to devote their lives to the honorable and beneficent career of teaching.

The instruction in highway engineering has been extended, and a set of notes prepared by Mr. Foss was printed and

used by the students last year. Two graduating theses were prepared which dealt specially with highway work: one being a study for the subdivision and laying out of a large tract of land; the other an investigation of the durability and physical properties of various kinds of paving brick. A foundry rattler was added to the engineering laboratory for use in connection with this latter thesis.

Special lectures were given during the year by Mr. John R. Freeman on hydraulics of fire protection and on fireproof construction, and one by Mr. F. P. Stearns, Chief Engineer of the State Board of Health.

Notes have been prepared and published for the use of the classes as follows:

(1.) A revised edition of Prof. Swain's notes on the Theory of Structures, for the third and fourth year classes.

(2.) Notes on Warped Surfaces, for the students in Stereotomy, by Prof. Porter.

(3.) A set of printed tables, prepared by Mr. E. B. Weston, giving friction losses in pipes, reprinted by permission from a report of the city engineer of Providence, for the use of students in hydraulic engineering.

(4.) A set of notes on Highway Engineering, prepared by Mr. Foss.

The equipment of the Hydraulic Laboratory has been increased during the past year by the addition of several important pieces of apparatus, among them one for the study of the discharge through diaphragms inserted in pipes, and another for the study of the conditions attending the flow through a branch inserted in a pipe. A large steel measuring tank with a capacity of 280 cubic feet has also been added. During the year experiments were also arranged for the study of the discharge through nozzles. The equipment of the laboratory will be still further increased this year. A three-inch Venturi meter, with registering apparatus, has been recently ordered of the Builders' Iron Foundry, in Providence; and the department has received as a loan from Mr. John R. Freeman a valuable collection of apparatus, used in his recent experiments on the flow of water through pipes, together with a very delicately constructed Pitot tube arranged for measuring the velocity at different points in the cross section of a pipe.

The laboratory has also received from the estate of the late James B. Francis, through the courtesy of his son, Col. James Francis, a very valuable collection of apparatus, used many years ago by Mr. Uriah Boyden and by Mr. Francis, consisting principally of a large number of beautifully made brass orifices of various forms. Col. Francis has also presented to the Institute a number of the original drawings of turbine wheels, made by Mr. Uriah Boyden.

Acknowledgment should also be made of the loan of a fifteen-inch Hercules turbine wheel, by the Holyoke Machine Company, of Worcester, which is used in connection with class-room instruction; also of a part of the apparatus used in the official tests of water meters by the commission appointed by the city of Boston in 1887, loaned by Mr. N. M. Lowe. Prof. C. Herschel Koyl has also presented the Institute with one of his parabolic semaphore signals, which has been set up in the third-year drawing room, where it is suitably illuminated.

The hydraulic field-work has, during the present year, been carried on at Lowell, through the courtesy of Col. Francis, gaugings having been made of the water flowing in the large Merrimack flume.

The outfit of geodetic and surveying instruments has not been materially increased. The apparatus for the accurate measurement of base-lines with the steel tape, designed under the direction of Prof. Burton, has been perfected, and was used in the summer school in the measurement of a base line about 2,000 feet long. This line was measured with a probable error of 0.016 inch, or one in one and a half million.

The library has been increased by the addition of a large number of valuable books and periodicals, among which may be mentioned a complete set, from the beginning (1877), of the "Revue Générale des Chemins de Fer," consisting of nineteen volumes. The library has also been enriched by the addition of a large number of sets of reports from the leading railroad companies in the United States and Canada, some of these sets being complete. Among these may be mentioned a complete set of the reports of the Pennsylvania Railroad, since 1847.

A large number of books relating to roads and highways have

been purchased with a portion of the fund contributed by Col. Albert A. Pope; and it is intended that the Engineering Library shall contain every book or pamphlet of importance on the subject of roads which it is possible to obtain.

A rather striking piece of testimony as to the professional value of the preparation received at the Institute is afforded by an article in a recent number (Oct. 20, 1892) of the *Engineering News*. This article gives the result of a comparison made by the editor between the number of students of civil engineering graduating, from 1860 to 1884, from the different schools in the country, and the number of such graduates who have attained to membership in the American Society of Civil Engineers. It appears, from the statements of the article in question, that the membership of this society is closely restricted.

"For the past fifteen years, at least, it has not been possible for any one to obtain admission to the society as a member, — however great his standing or acquirements in other lines, — unless he had risen to the rank of Chief or Principal Assistant Engineer, or had held a nominally lower rank on large works which was equivalent in responsibility to the positions named in smaller works. In other words, the intention has been — and with some possible individual exceptions, the practice — to admit no one as full member unless his past record warrants the belief that he is already fitted by experience to take charge of engineering works of some magnitude and importance."

Under these conditions, the editor deems the comparison referred to above a fair one, as showing, in regard to the body of graduates from each school, "the successful fraction of the engineering profession, namely, those who have followed the strict line of their profession with relatively greater persistency and success." The result of the comparison made, as the editor states it, is that "the Massachusetts Institute of Technology heads the list with the magnificent percentage of 32.2. The Rensselaer Polytechnic Institute of Troy follows with 21.5; while Washington University, St. Louis, is a strong third, with 20 per cent."

Course II. Mechanical Engineering. The most marked development in the department which should be noted this

year is that of the option in Naval Architecture, which is in charge of Prof. Peabody. When it is considered that it is only four years since this subject was first mentioned in our catalogue, it is truly remarkable that so near an approach has been made to a complete and thorough course. It would be difficult to find any other direction in which the Institute could develop which would have a greater promise of usefulness than this. The building of ships, both in the navy and in the merchant service, now imperatively demands men who are properly educated for the work. The day when that work could be done by those who had grown up from the condition of apprentices has passed by. This fact is fully recognized, and yet the number of young men so educated is exceedingly small, and the few Americans who have been educated at either the English or the French government school of Naval Architecture are in great demand.

The end which has been kept constantly in view, in developing this Option at the Institute of Technology, has been a course which should accomplish substantially the same results as the English and French government schools. Meanwhile we have sought to prepare our students to take positions, at first, as assistants in this kind of work, with, however, such an equipment and training as will qualify them to rise to positions of the largest responsibility after they have been in practice long enough.

After four years of effort and experiment in the direction of a substantial course in naval architecture, it has seemed appropriate to indicate to the Corporation as nearly as possible the point that has actually been reached in the development of these studies and exercises. I have, therefore, asked Prof. Lanza to give me the data for a somewhat extended statement regarding this branch of instruction at the Institute, in immediate comparison with what is known concerning the corresponding schools of the countries previously referred to.

In the foreign schools the student is given a very large amount of pure mathematics, with courses in mechanism, thermodynamics, and steam engineering, and in applied mechanics. The studies also embrace marine engineering, since the naval architect of to-day who is to engage in large works must be a marine engineer,

as well. In regard to all these subjects it may be said that, with the exception of the pure mathematics, they are taught as fully in our own course in Mechanical Engineering as in the English and French government schools of Naval Architecture, and in some cases, especially in thermodynamics and steam engineering, there is reason to believe that the work takes an even more practical and useful turn here, greater pains being taken to familiarize the student with the results of experiments up to date than is done in the foreign schools mentioned. In addition, our students have a good drill in work in the engineering laboratory, and are given two years of shop-work.

Next, as to the naval architecture proper: The time devoted to this study with us has this year increased, and now amounts to 420 hours. The class-room work is as follows: —

(*a*) Description of methods of building ships of iron and steel; including the transverse and longitudinal framing, and the fitting of ballast tanks and double bottoms; the laying out and erection of the framing, and the application of plating; and a discussion of bulkheads.

(*b*) Proofs and application of rules for finding the area, moment, moment of inertia, centre of gravity, and radius of gyration of lines, areas, and volumes, by Simpson's rule, the trapezoidal rule, and by the use of the Amsler-Laeffel integrator.

(*c*) General discussion of the properties of floating bodies, with a special application to ships. Discussion of the curves and surfaces of buoyancy and flotation, the metacentre and metacentric curves, statical and dynamical stability, including "metacentric stability." Application of the metacentric method to inclining experiments, for the determination of the centre of gravity of ships already built; to the discussion of variations of stability due to the addition or removal of weights, and to the effect of moving weights on the trim of the ship. Discussion of the effect of carrying fluids in tanks wholly or partially filled; the effect of filling wholly or partially the water-ballast tanks or the various compartments of the ship. The reserve of stability, or the effect of sudden forces, such as gusts or squalls of wind, on the safety of a ship under sail.

(*d*) Methods of finding the statical and dynamical stability of ships proposed by Barnes, Benjamin, Spence, McFarlane-Grey, Daymard, and others.

(*e*) Methods of finding the weight and centre of gravity of the hull, equipment, and cargo; determination of the loads, shearing forces, and bending moments acting on the hull of a ship in still water, or when borne by waves.

(*f*) Method of determining the equivalent girder for the hull of a ship, and the stresses on the hull produced by the weight of the hull, the equipment, and the cargo.

(*g*) Some discussion of waves and rolling of ships.

The drawing-room work is as follows: —

(*a*) Laying out and fairing the lines of a ship.

(*b*) Calculation of a displacement sheet, in the ordinary form.

(*c*) Drawing of curves of displacement, tons per inch of immersion, centre of buoyancy, areas of water lines, and transverse metacentre.

(*d*) Determination of metacentric stability.

(*e*) Calculation of statical and dynamical stability by Barnes' method and by the method in use at the Bureau of Construction and Repair of the Navy Department.

(*f*) Calculation of weight and centre of gravity of hull, equipment, and cargo.

(*g*) Calculation of stresses in the hull.

The above includes all the work done in the English government school, except the discussion of the rolling of ships in still water and among waves, which is a subject of less importance than the others, and one in which we can as yet do only a small amount of work, but which we shall take up more fully hereafter. While the amount of time spent in actual drill in doing the detail work is probably less with us than in the English government school, it is believed that by judicious management we can accomplish the object of putting the student in a condition where he will take hold of any of the work with a full understanding of what he is doing.

In the French school the instruction involves but little dock-yard or shop-work experience. In the English school the students have had, before they enter the school, at least five years in the dock-yard. They enter the yards at fourteen or fifteen years of age, and are made to work there in the shops and in the building of ships; receiving meanwhile instruction in mathematics, in-

cluding the calculus, and also in other branches. Hence, so far as their mathematics is concerned, they are as far along when they enter the school of Naval Architecture as our men are at the end of their second year, and they have also had some shop-work and done some of the work of shipbuilding. This dock-yard experience we cannot give; but, on the other hand, our men have our second and third year shop-work, and have also had the very great, the almost priceless, advantage of laboratory training in chemistry, mechanics, and physics, through which they acquire the ability to conduct measurements with care and precision, to perform experiments, and to undertake investigations. We are doubtless behind these foreign schools in the subject of pure mathematics; but this we hope will be remedied when our requirements for admission are raised.

From the foregoing it would appear, according to such light as we have on the subject of what the foreign schools are doing, that the Institute of Technology is now giving to its students as full a course in the theory of naval architecture as is given in the foreign schools, with the exception of a few things of minor importance, which will, however, be supplied in the immediate future; that our students are required to do the work of every part of the problem of designing a ship; that the resources of the department are such that the methods are all modern and the material worked upon is modern; that, by way of compensation for the lack of dock-yard experience, our students have some shop-work, and also have a large amount of chemical, physical, and engineering work in the several laboratories of the school. By way of material it may be said that we have most of the modern books on the subject, and that we have also a considerable amount of drawings, specifications, and lines of large and very modern steamers, naval and merchant, which material has been worked up into such shape that it can be, and is, freely used by the class.

It would be perfectly proper to consider the work done by the students in the naval architecture option in the light of a four years' course by itself, since it fulfils the purpose of such a course. It follows, therefore, that the work done in marine engineering should be mentioned, as this is closely allied to the work in naval architecture proper. This work includes: —

(*a*) Descriptions of marine and stationary engines in all their details, including the most modern types.

(*b*) The usual discussion and calculation of the strength and the proportions of the parts of marine engines.

(*c*) Discussion of the probable behavior of the steam in cylinders with different combinations and arrangements.

(*d*) Discussion of the effect of the reciprocating parts in combination with the preceding, with the object of determining the greatest stresses on the parts of the engine.

(*e*) Comparison of these results with the results of the usual methods.

(*f*) Discussion of paddle-wheels and screw-propellers.

The last four, viz., (*c*), (*d*), (*e*), and (*f*), include a large amount of drawing-room work and calculations by the students. With reference to this work the Institute is provided with a considerable amount of material, including a considerable number of modern books, and a large number of drawings, of which the most valuable are: —

(*a*) Drawings of the engines and boilers of the "Sagamore," a steam yacht built in 1889 at the Bath Iron Works; 48 drawings.

(*b*) Complete drawings of the machinery of the cruiser "Cincinnati," now building at the Brooklyn Navy Yard, including the engines (triple expansion of the latest type), boilers and location; about 193 drawings.

(*c*) Complete drawings of the boilers and engines of the three tug-boats built for the Treasury Department at City Point in 1891; 72 drawings.

(*d*) Drawings of an 18,000,000-gallon triple-expansion pumping engine, built by E. P. Allis & Co.

The credit for building up and developing both the course in Naval Architecture and that in Marine Engineering is mainly due to Prof. Peabody. It has involved, on his part, a very large amount of hard work and the exercise of a great deal of patience and of good judgment.

Delays which we have very much regretted, but which seemed unavoidable, have arisen in the completion of the Emery testing machine (300,000 pounds' capacity), so that it has only just arrived

from Philadelphia. It will be in place in season for the experimental work of the second term.

The publications made by different members of the department have been as follows: —

(*a*) Prof. Peabody has published his treatise on Valve-gears, which will enable a decided improvement to be effected in this part of the instruction.

(*b*) A paper was presented to the American Society of Mechanical Engineers by Profs. Peabody and Miller, giving an account of a very valuable series of tests on the triple-expansion engine in the laboratory.

(*c*) A paper was published in the *Technology Quarterly* by Prof. Sondericker, giving an account of a portion of his experiments on repeated stress.

The new sets of printed notes issued have been as follows: —

(*a*) Details of an eight-wheel locomotive by Prof. Lanza.

(*b*) A new and enlarged edition of Prof. Lanza's notes on Dynamometers, Planimeters, Governors, and Fly-wheels has been issued.

The department received in December, 1891, after the issue of the last report, a Wheeler condenser, having 150 square feet of cooling surface, presented by the Wheeler Condenser and Engineering Company.

Course III. Mining Engineering and Metallurgy. The additions recently made to the apparatus of this department have rendered our metallurgical plant fairly complete. A new ore-sampler, of a highly novel design by Prof. Richards, has just been finished and promises to be very useful. Prof. Hofman's new book on lead gives the latest facts and the best practice in the working of that metal. The conduct of the laboratory, under the personal direction of Profs. Richards and Hofman and Mr. R. W. Lodge, is all that could be desired. Our later graduates from Course III. are maintaining the high reputation won for the mining department of the school by the men of the first ten years.

Course IV. Architecture. Every effort has been made to prevent the instruction in this department from dropping down, even for a moment, in consequence of the death of Prof. Létang.

Prof. Chandler and his assistants have redoubled their attentions to the classes; while Mr. Mead, who undertook the charge of the work in architectural design upon Prof. Létang's sickness, has met with success far beyond our most sanguine expectations. Everything is being done, everything will be done, to save the students of the department from feeling that they have lost a single hour out of the year. Thus far things have gone smoothly. With greater facilities and ampler accommodations, we have been able to improve the courses in several respects. Last year, by special appropriation, the construction of diagrams and charts was carried so far that this year there is only needed such time to be given to them as can be spared from the duties of the regular assistants, whose skill and thoroughness leave nothing to be asked for. No department is destined to profit so largely as the department of architecture by the change, beginning the present year, through which students are to make choice of their respective courses at the end of the first term. This change has allowed some very important improvements to be effected in the architectural course, especially in the introduction of more of freehand drawing, and more of descriptive geometry.

The new building is proving to be wonderfully satisfactory. It is fitted with every material appliance required for the fullest and best professional and technical training. It has been furnished throughout by the generosity of Mr. Arthur Rotch. The number of students is about equal to that of last year, while there has been a distinct raising of the standard. More college graduates are in our architectural classes this year than ever before. The Technology Architectural Society has presented to the library Fossati's "Saint Sophia"; Adam's "Mediæval French Sculpture"; Gosset's "Les Coupoles d'Orient et d'Occident."

Postscript. — Since this report was made, the Corporation of the Institute has been informed of the acceptance by M. D. Despradelle, of the Associate Professorship of Architectural Design. M. Despradelle is from the Atelier Pascal, and was graduated from the École des Beaux Arts with distinction, at the unusually early age of twenty-five. He won nearly all the minor prizes of his time, and all but obtained the Prix de Rome, taking place as

Premier Second. Since graduation, M. Despradelle has already gained a position for himself in the profession. He is Sous-Inspecteur aux travaux des Bâtiments Civils des Monuments de l'État, and has the title of Architecte diplomé par le gouvernement, and also that of Architecte diplomé de la Société Centrale des Architectes Français. While M. Despradelle rightly feels that his future is an assured one in his present position, he has been attracted by the opportunities offered at the Institute of Technology, and has, as stated, accepted the Associate Professorship of Architectural Design. At such short notice M. Despradelle found it impossible to leave Paris in time to take up the work of our second term: but he will be with us in September. All that we have learned regarding M. Despradelle, both before and since the appointment, assures us that we could not have found in all France a worthier successor to Prof. Létang.

The Corporation and Faculty are under great obligations to Mr. Arthur Wheelwright and Mr. J. Randolph Coolidge, Jr., now resident in Paris, for most valuable advice and practical assistance in meeting this trying exigency of the Institute.

Course V. Chemistry. The changes in the Chemical Department during the past year have been numerous and important. The increasing number of students in the chemical laboratories, rising from 403 in 1890–91, to 449 in 1891–92, and to 528 in 1892–93, has necessitated a considerable increase in the space required for the work of the department, and this has resulted in a rearrangement of its work to a considerable extent. Few changes have been made in the topics taught, the only one of importance being the separation of the optical analysis of sugar from the organic laboratory work. Henceforth the former will constitute a distinct course, under the charge of Mr. Andrews.

In order to meet the increased demands caused by the number of students taking chemistry, the laboratories of the department have been rearranged to a considerable extent. The laboratory of general chemistry, which contained places for 320 students, was found too small last year, and during the summer its capacity was increased to 400, and this has proved only sufficient to meet the needs of the entering class. The space at the disposal of the de-

partment for laboratory work in general chemistry is now completely filled.

During the year the organic laboratory has been enlarged by the construction, in the upper hall of the Walker Building, of a convenient combustion room. The rooms heretofore occupied by Prof. Norton in the fourth story have been given to Prof. Pope and the instructors in general chemistry. The changes in the laboratories in the third story of the Walker Building have been extensive. Room 32 has been arranged as a private laboratory and office for Prof. Norton; while a portion of it has been made into a small recitation room, which was greatly needed by the department. Room 34 has been arranged as a storeroom for fine chemicals and apparatus, and as a preparation room for the large lecture room. The sanitary laboratory has been removed from room 34 to the larger and more convenient room number 38, and its capacity has thus been materially increased. Number 39 has been divided into an office room for Prof. Drown, and a spacious and convenient analytical laboratory which will be used by Prof. Drown and by advanced students in analytical chemistry.

Room 23 on the second floor has been arranged as a chemical and physical lecture room for the joint use of the departments of chemistry and physics. The seating capacity of the room is about seventy-five. A lecture room of this size has long been needed by these departments. The laboratories of sanitary chemistry have been used during the past year for the analysis of the waters of the State Board of Health as in previous years. Through the kindness of Henry D. Dupee, Esq., a number of interesting and instructive collections of chemical products exhibited in the Mechanics' Fair have been presented to the Institute, and will form a valuable addition to its collection. They will be placed in room No.30, which will be gradually transformed into a museum of chemical products.

Courses VI. and VIII. Electrical Engineering and Physics. No great change in the nature or arrangement of the work in these courses has been made during the past year; but there has been a steady gain in the quality of the instruction. Large additions have been made to the instrumental equipment of the

Rogers Laboratory, and various minor improvements in methods of instruction have been introduced. As a whole, the work done by the students has been better during the past year than ever before. A considerable amount of original scientific work has been carried on, and several papers from the department are ready for publication.

The very considerable accessions in the way of room which have been received by the department of physics during the past summer have come in good time to relieve a condition of increasing congestion which could not have continued longer without material injury to the work in physics and electrical engineering. These have allowed a large extension of our general laboratory space, and also enabled the department to set aside several rooms for work of a special character which could not be done properly in an apartment devoted to miscellaneous work. The principal changes are as follows: —

On the first floor, the small recitation room and the apparatus room, formerly occupying the space between room No. 10, the fourth-year laboratory, and the physical study, have been thrown into the former room, giving a spacious and well-lighted room, 108 feet in length and 29½ feet in breadth. This is devoted especially to the more advanced electrical work. A room of equal size for more elementary laboratory work has been secured on the opposite side of the hallway by throwing the room formerly occupied by the physical library into room No. 16. These two large rooms are admirably suited to their purpose of general instruction; and, so far as size, convenience, and abundance of daylight go, could hardly be bettered. Furthermore, the introduction of the electric light during the past year has allowed a considerable extension of working time.

The large hall on the first floor at the Newbury Street end of the Walker Building, 36½ x 56½ feet in area, which was among those newly assigned to the department, has been utilized in part to contain the physical library, and in part as an apparatus room. A partition has been run across the hall, dividing it into two rooms. That nearest the Rogers Building (36½ x 39½), containing a large number of windows, serves the purpose of a library and study room. It is very commodious, and will contain all the books which the depart-

ment is likely to receive for a long time to come, and will also meet the needs of the students of the department for a study room for several years. Some fear has been felt lest the location of the dynamo room underneath should produce disturbance; but no annoyance appears to have resulted from this cause. The second of the two rooms under consideration (with an area of 17 x 36½ feet), being devoid of window space, has been devoted to the purposes of an apparatus room. It is brilliantly lighted by incandescent electric lamps, so that there is no danger of breakage in moving the appa ratus to and from the cases. To avoid danger from fire, no other illuminant is used in the room.

Upon the second floor, changes and additions of equal magnitude and value have been made. The increased number of students taking second-year physics has necessitated the removal of most of the apparatus cases formerly placed against the inside wall of the physical lecture room (No. 22), in order to allow the introduction of additional seats. It is doubtful whether, even with this enlargement of seating capacity, it will suffice for more than a year or two longer. Room 23, adjoining the physical lecture room, has also been appropriated to the joint use of the departments of chemistry and physics, thus supplying what for the past three years has been one of the most pressing needs of the department, an additional lecture room with blackboard space, capable of seating from seventy to one hundred persons. A space between the temporary partition forming the rear of No. 23 and the rear wall of the Walker Building will probably have to be thrown into this room before long. Meanwhile it can be used for special laboratory work, as needed, chiefly in connection with thesis work.

The department of physics has furthermore been granted the use of the large room, No. 25, formerly occupied by the Architectural Department. This has been divided into several smaller rooms, as follows: A large room, 29½ x 33 feet in area, is set apart as a laboratory of acoustics. This will be devoted especially to advanced work in pure acoustics and telephony. A considerable amount of original research in these directions has already been done here; and it is hoped that, with the additional facilities now offered, this may be still further increased. The room is not yet complete as to

its final arrangements, but will be so in a few weeks. It will be provided with a very steady air-blast of variable pressure from a blower in the basement, for the purpose of sounding organ pipes, sirens, and like instruments, and with electricity both for lighting and for running such motors as are necessary to drive acoustic machinery. The latter will be run on separate circuits from those used for lighting, partly in order that greater steadiness in driving power may be secured, and partly that the alternating current may be used for lighting, if desired, while a direct current is used with the motors. The cabinet of acoustic apparatus will likewise be placed in this room. Experimental telephone lines will place it in communication with several other rooms in the laboratory. From this room at the north end open two smaller rooms, each about 15 x 15 feet. One of these is to be devoted to certain magnetic and electrical researches; the other, to the purposes of a study. A third small room opens from the acoustic laboratory on the side opposite to those first referred to. It occupies a space of 10 x 23 feet, and will contain the apparatus employed in the construction and comparison of resistance-coils. In it will be placed a standard Wheatstone's bridge, a galvanometer, a constant-temperature tank and other needful mechanical and electrical appliances. Between the last-mentioned room and the front of the building is an apartment, 29 x 29½ feet. This will be devoted to advanced work, especially to such optical or other work as requires the use of sunlight. Much of the optical apparatus will also find a place here. The rooms upon the second floor just described will greatly strengthen the Rogers Laboratory in a place where it has hitherto been especially lacking; that is, in the possession of rooms adapted for special as distinct from general work. The need of these has been urgent; and more efficient work may be hoped for than would have been possible without them.

Course VII. Biology. There were graduated from this department, at the close of the last academic year, six students, the largest number hitherto. Three of these were young women who immediately began their professional work by conducting with marked success large vacation classes in natural history at the seashore. In all, upwards of fifty persons were thus taught by them during the summer. Two of them have since secured positions

as teachers in institutions of high grade, and one has become a special assistant in a laboratory. The young men have also readily found positions of usefulness in their chosen profession.

There are now above sixty students of the Institute who spend more or less of their time in the biological laboratory. At the same time, a portion of the biological work of the State Board of Health is done here, and numerous special investigations are under way. Many of the subjects of investigation and instruction are such as to make it exceedingly desirable to have quiet and dust-free laboratories, but at present these must be carried on in the one general laboratory. It is becoming highly important that this department should have a suite of smaller laboratories in which the work upon the organisms of fermentation, putrefaction, and disease can more advantageously be conducted This department has not even a special lecture room of its own, most of its lectures being given in the general laboratory, which is well adapted to the more elementary classes, but inadequate to the needs of those more advanced.

Course IX. General Studies. The increase in the number of students is noticeable. About thirty students are now engaged in the special work of this course, and with them are some students from technical courses, who desire more of liberal studies than is contained in their prescribed curriculum, and can find the time to come into the classes of Course IX. for extra work. The number of graduates at the last Commencement was seven. Those subjects in this department which are required of the whole school were probably never brought in to such systematic form as they are to-day, and never were so well taught. In addition to the students engaged in the regular work of this department, large numbers of first, second, and third year students from all courses frequent the library and reading-room; and the methods of instruction bring each one of them into educational contact with the contents of the shelves and tables. The librarian's records do not by any means show the full extent of the use which the Institute students make of the Course IX. library; but it is noteworthy that during the scholastic year, 1891–92, there were 4,214 entries in the library register of volumes loaned to students. During the last year two graduate students from Wellesley College profited by the advanced instruction in

economics in the Institute. Two former members of Course IX. now hold fellowships in the School of Political Science in Columbia College, viz., Mr. W. Z. Ripley, of the class of 1891, and Mr. Francis Walker, who graduated with the class of 1892.

The lectures on Business Law, given by Mr. Louis D. Brandeis, of the Suffolk Bar, on each Saturday morning during the school year, constitute a distinct step forward in the history of this department. These lectures have been based upon valuable syllabus work; and are proving of the greatest interest and importance to the students.

Course X. Chemical Engineering. During the past year the course of instruction has not been changed further than by the introduction of a course of lectures given by Mr. Clifford upon photometry. Much, however, has been done in increasing the efficiency and perfecting the methods of instruction in the work given specially in this course. The number of students has continued to increase, rising from 28 in 1891–92 to 34 in 1892–93.

The President would repeat the statement made in the report last year, that a special laboratory, for research and testing work in connection with the course in chemical engineering, must very soon be provided, while it is probable that the number of students who are to graduate from this course in 1894 may make it necessary to provide additional laboratory space for this work during the coming summer. It is interesting to note that a demand has arisen for men trained in chemistry and in mechanical engineering to act as insurance inspectors. Three of the graduates from Course X. have entered upon this employment within a few months; and it is believed that others will be needed in the spring.

Course XII. Geology. It was not possible, on the short notice given, to find any one qualified to supply the place of Mr. Collier Cobb who, as stated, resigned his instructorship with us to accept an assistant professorship in the University of North Carolina. The teaching has consequently been done by others in the department. Additional clerical and mechanical assistance has been given to the teachers in this department, to enable them to carry on the work without loss. There have been no changes in the schedule of the geological course; but the increasing number of students has necessitated a division of some classes. These have

been made in such a way that the work could be further differentiated and thereby better adapted to the needs of students in the several courses which stand related, more or less intimately, to the geological department. The advanced work done by the students in the geological course during their fourth year has made it necessary to have a geological laboratory, and room 14 in the Rogers Building has been used to a considerable extent this year for that purpose. During the school year 1891–92, the names on the class-lists in the geological department amounted to 290.

There have been a goodly number of specimens of fossils added to the paleontological collection. Some work has been done in arranging and identifying the specimens and getting them ready to be catalogued, thereby making them more valuable for instruction. The books of the geological library are chiefly used in the room; but during the year there were 110 volumes borrowed from the library. Five different periodicals are regularly received through purchase or exchange.

Prof. Crosby and Mr. Barton have, during the past year, effected a very thorough revision and rearrangement of the teaching collections in mineralogy and lithology. The specimens are now arranged in permanent lesson-trays, each specimen being placed in a separate compartment and provided with a printed label. Eight identical series of specimens have been provided for the elementary work in mineralogy, and twelve series for the elementary work in lithology. These occupy in all nearly 600 wooden trays. The classes are divided into sections sufficiently small so that in general each student has at each lesson a separate tray of specimens; and it is found on actual trial that, as was anticipated, the new system makes it possible to introduce a much larger proportion of real laboratory work into the instruction, and enables the student to do more thorough work in less time than formerly. The new system has greatly diminished the time and labor of preparation for the lessons. The increased number of classes has made this economy very important.

Considerable additions have been made to the teaching collections in economic geology, the most important being a series of ores contributed by the National Museum. This series embraces

about 800 valuable specimens, and represents a large proportion of the mining districts of this country. Some very desirable illustrations, both of raw materials and manufactured products, have also been contributed without cost to the Institute, by the merchants and manufacturers of Boston and vicinity. Among the desiderata which have been purchased, may be mentioned a series of polished marbles; samples of all the more important tools and materials used in dressing and polishing stones; a complete series of mineral pigments, etc. Valuable additions to the collections have also been obtained by the personal visits of the instructors to mines and quarries.

The guide to the geological collections in the National History Building prepared by Prof. Crosby, having been published during the past year, has been adopted as a text-book in structural geology. Partly for the purpose of more perfectly adapting the guide to this use, but mainly because the charts and diagrams already in use exceed the available wall space on which they can be exhibited, Prof. Crosby has prepared a series of 86 plates, embracing nearly 200 figures, which have been reproduced at the expense of the Institute. These illustrations, which have been culled chiefly from the reports of the government surveys, and are in most cases faithful copies or photographic reproductions of nature, may be regarded as an extension of object teaching beyond the use of specimens or the possibility of field lessons.

During the semi-annual vacation, Prof. Crosby, in company with Mr. H. D. Card, a fourth-year student in economic geology, spent ten days in visiting iron, coal, and other mines, and slate quarries and factories in New Jersey and Eastern Pennsylvania, and also in studying the extensive economic collections in the National Museum at Washington. The summer field work in Mineralogy was done in July, one week being spent by Prof. Crosby and sixteen students in visiting the celebrated localities of Paris, Me, and the adjoining towns. The students became greatly interested in the work, and the session of this summer, though brief, was in every way successful.

COMMONWEALTH OF MASSACHUSETTS.

BOSTON, January 2, 1892.

I certify *the annexed to be a true copy of the opinion of the Supreme Judicial Court in the case of* Massachusetts Agricultural College *v.* Marden, *decided on the 29th day of March, 1892.*

GEO. F. TUCKER,
Reporter of Decisions.

MASSACHUSETTS AGRICULTURAL COLLEGE *v.* GEORGE A. MARDEN.

SUFFOLK. January 15, 18, 1892. — March 29, 1892.

Present: ALLEN, HOLMES, KNOWLTON, MORTON, LATHROP, AND BARKER, JJ.

Act of Congress — Claimants to Fund.

Where the Massachusetts Agricultural College and the Massachusetts Institute of Technology were claimants to a fund paid to the Treasurer and Receiver General, conformably to the provisions of an act of Congress approved August 30, 1890, entitled "An act to apply a portion of the proceeds of the public lands to the more complete endowment and support of the colleges for the benefit of agriculture and the mechanic arts established under the provisions of an act of Congress approved July second, eighteen hundred and sixty-two," it was *held* that it was for the Legislature to determine to which of the claimants it would give the fund, or whether it would give a part of it to one and a part to the other; and that the Treasurer and Receiver General had no right to pay out the fund until he was directed so to do by the State.

PETITION for a writ of mandamus to compel the respondent to pay over to the treasurer of the petitioner a fund received by the respondent under the act of Congress approved August 30, 1890. Hearing before *Holmes*, J., who reserved the case for the determination of the full court.

The case was argued at the bar in January, 1892, and afterwards was submitted on the briefs to all the judges except *Field*, C. J.

F. E. Snow (*W. A. Gaston* with him), for the petitioner.

A. L. Lowell, for the respondent.

KNOWLTON, J. By an act of Congress, approved August 30, 1890, entitled "An act to apply a portion of the proceeds of the public lands to the more complete endowment and support of the colleges for the benefit of agriculture and the mechanic arts established under the provisions of an act of Congress approved July second, eighteen hundred and sixty-two," it was provided "That there shall be, and hereby is, annually appropriated, out of any money in the treasury, not otherwise appropriated, arising from the sales of public lands, to be paid as hereinafter provided, to each State and Territory for the more complete endowment and maintenance of colleges for the benefit of agriculture and the mechanic arts now established, or which may be hereafter established, in accordance with an act of Congress approved July second, eighteen hundred and sixty-two, the sum of fifteen thousand dollars for the year ending June thirty, eighteen hundred and ninety, and an annual increase of the amount of such appropriation thereafter for ten years by an additional sum of one thousand dollars over the preceding year, and the annual amount to be paid thereafter to each State and Territory shall be twenty-five thousand dollars, to be applied only to instruction in agriculture, the mechanic arts, the English language, and the various branches of mathematical, physical, natural, and economic science, with special reference to their applications in the industries of life and to the facilities for such instruction," this appropriation being subject to certain conditions in cases where any distinction is made in the admission of students by reason of race or color.

The second section of the act contains this provision: "The sums hereby appropriated to the States and Territories for the further endowment and support of colleges shall be annually paid on or before the thirty-first day of July of each year, by the Secretary of the treasury, upon the warrant of the Secretary of the Interior, out of the treasury of the United States, to the State or Territorial treasurer, or to such officer as shall be designated by the laws of such State or Territory to receive the same, who shall, upon the

order of the trustees of the college, or the institution for colored students, immediately pay over said sums to the treasurers of the respective colleges or other institutions entitled to receive the same, and such treasurers shall be required to report to the Secretary of Agriculture and to the Secretary of the Interior, on or before the first day of September of each year, a detailed statement of the amount so received, and of its disbursement. The grants of moneys authorized by this act are made subject to the legislative assent of the several States and Territories to the purpose of said grants; provided, that payments of such instalments of the appropriation herein made as shall become due to any State before the adjournment of the regular session of Legislature meeting, next after the passage of this act shall be made upon the assent of the Governor thereof, duly certified to the Secretary of the Treasury."

By § 4 of said act it was provided "That on or before the first day of July in each year, after the passage of this act, the Secretary of the Interior shall ascertain and certify to the Secretary of the Treasury as to each State and Territory whether it is entitled to receive its share of the annual appropriation for colleges, or of institutions for colored students, under this act, and the amount which thereupon each is entitled, respectively, to receive. If the Secretary of the Interior shall withhold a certificate from any State or Territory of its appropriation the facts and reasons therefor shall be reported to the President, and the amount involved shall be kept separate in the treasury until the close of the next Congress, in order that the State or Territory may, if it should so desire, appeal to Congress from the determination of the Secretary of the Interior. If the next Congress shall not direct such sum to be paid it shall be covered into the treasury. And the Secretary of the Interior is hereby charged with the proper administration of this law."

Under this act, a payment of $15,000 for the year ending June 30, 1890, has been made out of the treasury of the United States to the respondent, who is the Treasurer and Receiver General of Massachusetts, and the principal question presented by this petition is what disposition shall be made of the money in his hands.

This first instalment of $15,000 became due before the adjournment of the regular session of the Legislature meeting next after

: of the act, and, in reply to a communication from the
f the Interior, the Governor, in behalf of the Common-
:nted to the purpose of the grant, as provided in § 2.
ng a series of questions contained in the letter of the
)f the Interior, he showed that the petitioner was a
:ablished and maintained in accordance with the act
ss of July 2, 1862, and it thereby appeared that the
:ntitled to have the money paid over to its Treasurer and
Seneral. There was nothing in the reply of the Governor
: that there was more than one such college in this Com-
L.

assachusetts Institute of Technology has been made a
these proceedings, and in its behalf it is now contended
in institution which comes within the provisions of the act
1862, and that it ought to receive from the respondent a
is money.

it inquiry is whether it is such an institution as is contem-
the act, and whether the establishment and maintenance
entitle the State to receive the money if the Massa-
ricultural College were not in existence. By the terms
each of the States was to receive certain public lands,
ds of which were to constitute a perpetual fund, "the
which shall be inviolably appropriated, by each State
take and claim the benefit of this act, to the endow-
port, and maintenance of at lease one college where the
bject shall be, without excluding other scientific and
studies, and including military tactics, to teach such
of learning as are related to agriculture and the mechanic
ch manner as the Legislatures of the States may respec-
scribe, in order to promote the liberal and practical edu-
the industrial classes in the several pursuits and professions

assachusetts Institute of Technology was incorporated
:. of 1861, c. 183, § 1, "for the purpose of instituting
taining a society of arts, a museum of arts, and a school
ial science, and aiding generally, by suitable means, the
ent, development, and practical application of science

in connection with arts, agriculture, manufactures, and commerce." In pursuance of the requirements of the statute, a school of industrial science was afterwards established, and through the school and otherwise the Institute has been carrying out the purpose of its incorporation. All that is required by the act of Congress is that the leading object of the institution shall be to teach "such branches of learning as are related to agriculture and the mechanic arts," "without excluding other scientific and classical studies." Under this statute agriculture is given no preference over the mechanic arts. A proper school of industrial science would be expected to give such instruction as the statute calls for, especially when it aims at "the advancement, development, and practical application of science in connection with arts, agriculture, manufactures, and commerce." Looking at the object of this corporation as defined by its charter, it would seem as if its corporators had anticipated in our State the purpose of Congress, embodied in the statute which we are considering. This seems to have been the view of our legislators of that time; for having by the St. of 1863, c. 166, accepted the grant of Congress, and created "a fund for the promotion of education in agriculture and the mechanic arts," they then, by the St. of 1863, c. 186, granted to the Massachusetts Institute of Technology one third of the income of the fund, and at the same time amended its charter so as to require it to teach military tactics in conformity with the provisions of the act of Congress, and made the Governor, the Chief Justice of the Supreme Judicial Court, and the Secretary of the Board of Education each a member *ex officio* of the government of the Institute. They also required the Institute to furnish to the Governor and Council a copy of the annual report of its operations. The Institute accepted the grant and the amendment to its charter, and established the school of industrial science. Afterwards, in the same year, by the St. of 1863, c. 220, two thirds of the income of the fund was granted to the Massachusetts Agricultural College, which was then incorporated to receive it. Since then, the income of this fund has heen annually divided between the two coporations in the proportion of two thirds to the petitioner and one third to the Massachusetts Institute of Technology. This is

strongest possible legislative declaration that both of the cor-
ations are within the description of the Act of Congress. If they
e not, the appropriation of any part of the income to the Insti-
of Technology would be a violation of the sacred trust under
ch the bounty of the general government was received. It is be-
ed that few of the institutions which are receiving the income of
ls established under this act are in their organization so near
his is to the very language of the act. They could hardly be
rer without using the precise words of the statute.

'he claim of this corporation is not affected by the fact that its
rter was granted prior to the passage of the act of Congress.
t act contemplates the endowment of colleges already in exist-
:, as well as of those afterwards to be established. All that is
ıired is that the college shall be of the prescribed kind. The
ıt is to be appropriated "to the endowment, support, and
ntenance of at least one college," etc., not necessarily to the
blishment of a new college. This point was involved in the
ision in *Liggett* v. *Ladd*, 17 Oregon, 89, and in an opinion of
Supreme Court of Rhode Island, holding that Brown University
ıtitled to receive the benefit of the fund. *In re Agricultural*
ds, Index H H, Dec. Sup. Ct. R. I., Oct. Term, 1890, 159.

can it be held that the fund is necessarily to be for the benefit
y one college in each State. The act of 1862 plainly con-
ıtes the possible existence of more than one college of the
escribed in each State. In § 4 the grant is said to be for the
ment "of at least one college." Under § 5, cl. 3, each State
provide, within five years, at least not less than one college."
:ts of 1866 (39th Cong. 1st Sess. c. 209), of 1872 (42d
2d Sess. c. 55, 42d Cong. 3d Sess. cc. 2 and 50), and of
49th Cong. 2d Sess. c. 314), all show that under the act of
here may be two or more colleges in each State entitled to
n the funds.

act of 1890 provides "for the more complete endowment
ıintenance of colleges for the benefit of agriculture and the
nic arts now established, or which may be hereafter estab-
in accordance with an act of Congress approved July 2, 1862."
ıcludes all such colleges, and there is nothing in it to restrict

the States in the use of the money to one college in each State. They are colleges established "in accordance with" the act, not necessarily under it and subsequent to it. The benefit of the fund is confined to one college for white students only in those States where a separate institution is maintained for colored students, and in those, with a view to an equitable distribution between the two classes, a division is made between one college for white students, and one institution for colored students.

The money in the hands of the Treasurer and Receiver General is the property of the State, held under the law for a particular use and for no other. Whether the State has or has not power to control it in his hands otherwise than to direct the use of it in conformity with the act of Congress, it is clear that neither the State nor the respondent has a legal right to divert it, and that, if there are different ways in which it may be used under the provisions of the statute of the United States, the State alone, acting by its Legislature, can choose between them. *Cornell University* v. *Fiske*, 136 U. S. 152, 203. *People* v. *Davenport*, 117 N. Y. 549. That the Secretary of the Interior, when he drew his warrant for the payment to the respondent, knew of but one college that could properly receive the money is immaterial; for the appropriation by Congress was to the State, and the payment to the respondent was for the use of the State, and the only limitation on the right of the State is to use it for the more complete endowment and maintenance of a college, or of the colleges, established in accordance with the act of 1862. The duty of the Secretary was performed when he determined that the State was entitled to it, and drew his warrant for the payment of it. It should be added that that part of the first section which says that the money shall be "applied only to instruction in agriculture, the mechanic arts," etc., may prevent the use of it in some departments of instruction existing in colleges established in accordance with the act of 1862; for by the terms of the act they are to have a "leading object, . . . without excluding other scientific and classical studies." It is possible that some kinds of classical instruction furnished by some of these colleges cannot be paid for from money received under the act of Aug. 30, 1890. On this point we give no opinion.

jdicature should determine to which of the two claimants
: the fund in the hands of the respondent, or whether
: a part of it to one and a part to the other. The re-
as no right to pay it out until he is directed so to do by
In the opinion of a majority of the court, the petition
ure be dismissed. *Petition dismissed.*

TREASURER'S REPORT.

STATEMENT OF THE TREASURER.

The Treasurer submits the annual statement of the financial affairs of the Institute for the year ending Sept. 30, 1892: —

The principal unusual expenditure of the year has been that on account of the new building for the Department of Architecture, amounting for the time covered by this report to thirty-four thousand nine hundred and thirty-one dollars and thirty-two cents ($34,931.32).

The principal amounts received from other than the regular sources of income have been twenty-two thousand dollars received under the Act of Congress of Aug. 30, 1890, covering four annual payments, and sixteen thousand two hundred and fifty dollars received from subscriptions constituting part of a fund to be raised to cover the cost of the new building already referred to, and to meet the other pressing needs of the Institute.

There has also been received from Mrs. Wm. B. Rogers the sum of two hundred dollars for the purchase of periodicals.

Bonds of the face value of twenty-eight thousand dollars have during the year matured and been paid. Twenty-five thousand dollars of the above bore interest at eight per cent, two thousand at seven per cent, and one thousand at six per cent. These investments were made at a time when rates of interest were higher than now, and the reinvestment of these funds at the present rates will result in a decreased income for the Institute.

Notes receivable, amounting to twenty-five thousand four hundred and seventy-six dollars and seventy-five cents, have been paid, and the following changes in securities have been made: —

SALE OF SECURITIES, GENERAL FUND.

) Burlington & Missouri River R. R. in Neb. 6s, called	$1,000 00	
) Quincy & Palmyra R. R. 8s, exchanged	25,250 00	
) Hannibal & St. Joseph R. R. 6s, sold,	25,685 00	
) Cincinnati & Indiana R. R. 7s, paid	2,000 00	
o, Burlington & Quincy R. R. Rights, sold	115 50	
res Chicago, Burlington & Quincy R. R., sold	16,458 75	
Chicago, Burlington & Quincy R. R., 7s, 1903, transferred to Rogers Memorial Fund	8,715 00	
		$79,224 25

SALE OF SECURITIES WM. B. ROGERS MEMORIAL FUND.

) Chicago Junction & Union Stock Yards, 5s	$35,137 50	
o, Burlington & Quincy R. R. Rights	165 00	
ares Chicago, Burlington & Quincy R. R.	23,512 50	
		$58,815 00

following securities have been bought: —

PURCHASE OF SECURITIES, GENERAL FUND.

) Burlington & Missouri River R. R. in Neb. 6s, 1918, non-exempt	$1,030 00	
) New York & New England R. R. First 6s, 1905	14,510 00	
) Hannibal & St. Joseph R. R. 6s, 1911,	27,500 00	
) Eastern R. R. of Minnesota 5s, 1908,	25,125 00	
) Chicago, Burlington & Quincy R. R. Conv. 5s, 1903	16,283 55	
		$84,448 55

RCHASE OF SECURITIES, WM. B. ROGERS MEMORIAL FUND.

) Chicago, Burlington & Quincy R. R. Conv. 5s, 1903	$23,882 53	
) Fort Street Union Depot 4½s, 1941	34,825 00	
		$58,707 53

income of the Institute for the past year has been divided at the five per cent among the funds to which it belongs.

net result of the year has been, apart from the cost of the new ıg, an expenditure over income of three thousand two hundred xty-two dollars and twelve cents ($3,262.12), which has been ɔd against Massachusetts Institute of Technology Account.

GEORGE WIGGLESWORTH, Treasurer, *in account with*

General Statement of Receipts and Disbursements

Dr.

Cash balance Sept. 30, 1891		$9,004 79
From Augustus Lowell for Lowell Courses	$3,900 00	
" " " " C. Kastner's salary	2,500 00	
" " " " Lowell School of Design	1,333 33	
		7,733 33
Receipts for Current Expenses.		
Income of funds for salaries	$4,380 00	
" " " " scholarships (students' fees)	3,665 00	
" " " " Joy "	200 00	
" " " " Swett "	400 00	
" " " " Library	250 00	
" " " " general purposes	10,389 12	
" " Rogers Memorial Fund	12,511 25	
Students' fees	185,873 77	
State Agricultural Fund	5,712 93	
State Endowment Fund, 4 years	22,000 00	
Laboratory breakage and supplies	4,422 99	
Rents, per Table (page 78)	7,115 50	
Gifts	200 00	
Interest	2,328 77	
Pope Fund for Highway Engineering	1,200 00	
" " used from balance of 1891	66 11	
Boston University	1,150 00	
Sale printed Lecture Notes	2,339 95	
Society of Arts	80 39	
Profit and Loss, expenses more than income (see per contra)	3,262 12	
		267,547 90
Bequests, New Trusts, Etc.		
Letter Box Fund, received	$126 70	
Income James Savage Fund, not used	573 62	
" James H. Mirrlees Fund, " "	12 36	
" William Barton Rogers Fund, " "	22 27	
" Elisha Thacher Loring Fund, " "	24 57	
" Richard Perkins Fund, " "	320 26	
" Charlotte Billings Richardson Fund, " "	1,541 25	
" Charles Lewis Flint Fund, " "	56 87	
" Joy Fund, " "	396 20	
		3,074 10
Sale of Securities, General Fund.		
See list as per page 69.		79,224 25
Sale of Securities, Wm. B. Rogers Memorial Fund.		
See list as per page 69.		58,815 00
Sundries.		
Notes Receivable paid	$25,476 75	
Subscription of 1892	16,250 00	
Net gain on sales of Bonds and Stocks, 1883 to 1892	4,951 17	
New boiler account charged to expense	5,000 00	
Income General Funds credited to Advance Bond Premium Account, $453.24 and $44.72	497 96	
Income Wm. B. Rogers Memorial Fund credited to Advance Bond Premium Account, $249.23 and $186.97	436 20	
Balance Account Lowell School of Design, 1883 to 1892, charged to General Expense	720 66	
		53,332 74
		$478,732 11

SACHUSETTS INSTITUTE OF TECHNOLOGY.

FOR THE YEAR ENDING SEPTEMBER 30, 1892.

Cr.

owell Courses	$3,900 00	
harles Kastner's salary	2,500 00	
xpense Lowell School of Design	1,592 02	
		$7,992 02

EXPENSES.

er Table (page 78)	$179,767 94	
aid from the Pope Fund	900 00	
" " " " "	366 11	
ips paid from Swett Fund	200 00	
" " Rogers Fund	90 00	
er Table (page 78)	8,500 83	
xpense, per Table (page 79)	12,233 94	
. 2, Balance Account	5,000 00	
	8,766 61	
	1,485 00	
	2,011 10	
nd Advertising	3,242 86	
ecture Notes	2,522 23	
Annual Catalogue	1,934 09	
l Boston & Albany R. R. Co.	180 00	
Natural History Society	400 00	
y Supplies and Libraries, per Table).	29,523 24	
per cent on funds not in stocks and	9,423 95	
aid A. Lowell, Trustee	1,000 00	
		267,547 90

INVESTMENTS, ETC.

SECURITIES, GENERAL ACCOUNT.

Burlington & Missouri River R. R., Neb., 6s, non-exempt	$1,030 00	
Hannibal & St. Joseph R. R., 6s	27,500 00	
Eastern R. R., of Minnesota, 5s	25,125 00	
Chicago, Burlington & Quincy R. R., Conv. 5s	16,283 55	
New York & New England R. R., First 6s	14,510 00	
Foy Scholarship Fund deposited	396 20	
		84,844 75

RITIES BOUGHT FOR WM. B. ROGERS MEMORIAL FUND.

Kansas City, Memphis & Birmingham R. R., Coupon Note	$250 00	
Chicago, Burlington & Quincy R. R., Conv. 5s	23,882 53	
Fort Street Union Depot 4 1-2s	34,825 00	
Chicago, Burlington & Quincy R. R., 7s, 1903, transferred from General Securities	8,715 00	
		67,672 53

SUNDRIES.

m Building Addition	$2,402 24	
Notes Receivable	5 00	
Deposits paid	50 00	
l, used from balance of 1891	66 11	
n Sales of Bonds and Stocks, 1883	4,951 17	
' Building	34,931 32	
Loss, per contra	3,262 12	
		45,667 96
nce, Sept. 30, 1892		5,006 95
		$478,732 11

The following account exhibits the property held by the Institute, as per Treasurer's books, Sept. 30, 1892:—

INVESTMENT OF THE W. B. ROGERS MEMORIAL FUND.

$50,000 00	Saginaw & Western R. R. 6s		1913	$50,000 00	
30,000 00	Burlington & Mo. River R. R., 4s		1910	25,787 50	
25,000 00	Kansas City Belt R. R. 6s		1916	25,000 00	
20,000 00	Mo. Valley Blair Ry. & Bridge Co. 6s		1923	20,000 00	
18,000 00	Atchison, Topeka & Santa Fé R. R. 4s		1989	15,372 30	
16,000 00	Kansas City, Clinton & Springfield R. R. 5s		1925	16,000 00	
7,000 00	Omaha & Southwestern R. R. 8s		1896	7,000 00	
5,400 00	Republican Valley R. R. 6s		1919	5,400 00	
4,000 00	Cin., Ind. St. Louis & Chicago R. R. 6s		1920	4,000 00	
2,000 00	Ottawa, Oswego & Fox River R. R. 8s		1900	2,000 00	
2,000 00	New York & New England R. R. First 6s		1905	2,000 00	
2,000 00	Kansas City, Fort Scott & Gulf R. R. 7s		1908	2,000 00	
2,000 00	Kansas City, Memphis & Birmingham R. R. 5s		1927	1,905 00	
250 00	" " " Coupon Note		1901	250 00	
1,000 00	Lincoln & Northwestern R. R. 7s		1910	1,000 00	
1,000 00	Atchison & Nebraska R. R. 7s		1908	1,000 00	
7,000 00	Chicago, Burlington & Quincy R. R. 7s		1903	7,000 00	
22,000 00	" " " " Conv. 5s		1903	22,000 00	
35,000 00	Fort Street Union Depot 4½s		1941	34,825 00	
	Advances to Bond Premium account			7,533 91	
	Bonds				$250,073 71

INVESTMENT OF THE JOY SCHOLARSHIP FUND.

	Massachusetts Hospital Life Insurance Co.	$5,000 00	
	Deposits in Savings Banks	3,555 83	
			8,555 83

INVESTMENT SWETT SCHOLARSHIP FUND.

	Massachusetts Hospital Life Insurance Co.	10,000 00

INVESTMENT OF OTHER TRUSTS.

$50,000 00	Atchison, Topeka & Santa Fé R. R. 6s		1893	$50,000 00	
18,000 00	Bur. & Mo. River (Neb.) R. R. 6s, non-exempt,		1918	18,000 00	
15,000 00	" " (Land Grant) R. R. 7s	1893		15,000 00	
6,000 00	Chicago, Burlington & Quincy R. R. 4s		1922	5,100 00	
3,000 00	Milwaukee & St. Paul R. R. 7 3-10		1898	3,000 00	
2,000 00	Chicago, Burlington & Northern R. R. 5s		1926	2,000 00	
2,000 00	Kansas City Fort Scott & Gulf R. R. 7s		1908	2,000 00	
1,000 00	International & Great Northern R. R. 6s		1919	1,000 00	
1,000 00	Union Pacific R. R. 6s		1898	1,000 00	
13,000 00	New York & New England R. R. First 6s		1905	13,000 00	
3,000 00	Hannibal & St. Joseph R. R. 6s		1911	3,000 00	
25,000 00	Eastern R. R. of Minnesota 5s		1908	25,000 00	
15,000 00	Chicago, Burlington & Quincy R. R. Conv. 5s		1903	15,000 00	
	Advances to Bond Premium account			2,183 19	
	Bonds				155,283 19
	Amount carried up				$423,912 73

brought up				$423,912 73

STOCKS.

on & Albany R. R.,	par	100	$29,933 00	
ieco Manufacturing Co.,	"	500	6,000 00	
Boston National Bank,	"	100	5,510 50	
ilton Woollen Co.,	"	100	5,000 00	
ris & Essex R. R.,	"	50	6,150 00	
x Co.,	"	50	4,050 00	
sylvania Coal Co.,	"	50	11,250 00	
ett Mills,	"	100	3,150 00	
York & Harlem R. R.,	"	50	5,000 00	
burg, Fort Wayne & C. R. R.,	"	100	3,000 00	
olidated Gas Co., New York,	"	100	1,447 50	
				80,491 00

REAL ESTATE.

Building			$315,726 88	
Building			190,492 44	
Garrison Street .	$50,840 00			
ops " " .	52,416 49			
			103,256 49	
Trinity Place .	$76,315 69			
ring B'ld'g, Trinity Place	106,616 87			
			182,932 56	
ium Building			7,742 85	
ts' Building			34,931 32	
				835,082 54
ent, Engineering Building . .			$16,555 24	
Workshops			20,628 56	
				37,183 80

SUNDRIES.

eceivable			$1,500 00	
s' Notes			2,405 00	
lance, Sept. 30, 1892			5,006 95	
				8,911 95
				$1,385,582 02

The foregoing Property represents the following Funds and Balances and is answerable for the same.

The Income of the following is used for the general purposes of the Institute: —

William Barton Rogers Memorial Fund	$250,225 00	
Richard Perkins Fund	50,000 00	
George Bucknam Dorr Fund	49,573 47	
Martha Ann Edwards "	30,000 00	
Nathaniel C. Nash "	10,000 00	
Sidney Bartlett "	10,000 00	
Robert E. Rogers "	7,680 77	
Albion K. P. Welch "	5,000 00	
Stanton Blake "	5,000 00	
McGregor "	2,500 00	
General Institute "	36,028 00	
		$456,007 24

The Income of the following is used towards paying salaries: —

Nathaniel Thayer, for Professorship of Physics,	$25,000 00	
Jas. Hayward, for Professorship of Engineering,	18,800 00	
William P. Mason, " Geology	18,800 00	
Henry B. Rogers, for General Salaries	25,000 00	
		87,600 00

SCHOLARSHIP TRUSTS.

Richard Perkins Fund	$52,575 46	
James Savage Fund	12,045 96	
Mrs. Susan H. Swett Fund	10,182 95	
William Barton Rogers Fund	8,857 78	
Joy Fund	8,555 83	
Elisha Thacher Loring Fund	5,266 09	
Charles Lewis Flint Fund	5,194 22	
Thomas Sherwin Fund	5,000 00	
Farnsworth Fund	5,000 00	
James H. Mirrlees Fund	2,659 63	
		115,337 92

OTHER TRUSTS.

Charlotte Billings Richardson, Industrial Chemistry Fund,	32,366 25
Charles Lewis Flint, Library Fund	5,000 00
Albert A. Pope, Street Building and Highway Engineering, Fund, balance	715 01
Letter Box Fund, balance	209 37

MISCELLANEOUS.

Notes Payable	$20,000 00	
Students' Deposits	400 00	
Subscription of 1887	123,500 00	
Subscription of 1892	16,250 00	
M. I. T. Stock Account	528,196 23	
		688,346 23
		$1,385,582 02

COMPARATIVE STATEMENT OF FUNDS, ETC.

	Sept. 30, 1891.	Sept. 30, 1892.
general purposes . . .	$456,007 24	$456,007 24
Salaries	87,600 00	87,600 00
Scholarships	113,931 77	115,337 92
Library	5,000 00	5,000 00
Billings Richardson Industrial stry Fund	30,825 00	32,366 25
Pope Street Building and High-ngineering Fund . . .	781 12	715 01
r Fund	82 67	209 37
able	20,000 00	20,000 00
Deposits	450 00	400 00
on of 1887	123,500 00	123,500 00
" 1892		16,250 00
ock Account	526,507 18	528,196 23
	$1,364,684 98	$1,385,582 02
. . . . .	20,897 04	
ng of: —		
Billings Richardson Fund In-		
. . . . .	$1,541 25	
p Funds, not used . . .	1,406 15	
r Fund, increase . . .	126 70	
on of 1892	16,250 00	
on Sales of Bonds and Stocks, o 1892	4,951 17	
		$24,275 27
Expenses more than Income	$3,262 12	
. A. Pope Fund . . .	66 11	
tudents' Deposits . . .	50 00	
		3,378 23
		$20,897 04

INCOME FROM GENERAL INVESTMENTS, AND APPLICATION THEREOF.

Applied to	Salaries	$4,380 00	From	Dividends, Old Boston National Bank	$330 00
"	" Scholarships	3,665 00	"	State Tax returned, Old Boston National Bank	78 89
"	" Library	250 00	"	Railroad Bonds	8,347 97
"	" General Purposes	10,389 12	"	Dividends, Pittsburg, Ft. W. & C. R. R. Stock	140 00
"	" Increase of Funds	2,551 20	"	Dividends, Pennsylvania Coal Co.	600 00
"	" Advances to Bond Premiums	453 24	"	" Everett Mills	210 00
			"	" Essex Co.	162 00
			"	" Cocheco Mfg. Co.	240 00
			"	" Consolidated Gas Co., N.Y.	105 00
			"	" Chicago, Bur. & Q. R. R.	365 75
			"	" New York & Harlem R. R.	210 00
			"	" Hamilton Woollen Mills	300 00
			"	" Morris & Essex R. R.	287 00
			"	" Boston & Albany R. R.	888 00
			"	Interest on Funds not in Bonds and Stocks @ 5%, being the rate of earnings of the other invested funds	9,423 95
		$21,688 56			$21,688 56

INCOME FROM WILLIAM BARTON ROGERS MEMORIAL FUND, AND APPLICATION THEREOF.

Paid Massachusetts Institute of Technology 5%		Received Income from Railroad Bonds .	$12,237 98
on Amount of Fund ($250,225.00) .	$12,511 25	" Dividend 220 Shares Chicago,	
Credited to Advances Bond Premiums .	249 23	Burlington & Quincy R. R. .	522 50
	$12,760 48		$12,760 48

DETAILS OF SOME ITEMS IN TREASURER'S CASH ACCOUNT.

Rents.

Huntington Hall, for Lowell Lectures	$3,200 00	
Lowell School of Design	1,800 00	
Chauncy Hall School, for Gymnasium	500 00	
State Board of Health, for use of Laboratories	900 00	
Boston Water Works, use of Laboratory	300 00	
Use of Lecture Rooms and Gymnasium	415 50	
		$7,115 50

Department Supplies.

Chemical Department	$7,722 25	
Physical "	5,005 37	
Mining "	1,549 03	
Mechanical Eng'r'g "	2,874 15	
Applied Mechanics "	1,223 41	
Civil Engineering "	2,865 79	
Biological "	1,730 32	
Geological "	870 06	
Architectural "	1,408 62	
Drawing "	51 59	
Mathematical "	10 27	
English "	1,185 36	
Workshops	1,604 80	
Modern Languages	218 91	
Periodicals	1,203 31	
		$29,523 24

Salaries.

Instruction	$147,373 05	
Administration	16,746 64	
Labor	15,648 25	
		$179,767 94

Repairs.

Department Improvements: —		
Chemical Department	$1,454 12	
Physical "	692 39	
Workshops "	431 79	
Mechanical Eng'r'g "	423 01	
Civil " "	186 99	
Amount carried forward	$3,188 30	

Amount brought forward	$3,188 30		
Architectural Department	114 96		
Mining "	106 91		
Modern Language "	103 49		
English "	83 03		
Biological "	50 80		
Geological "	38 14		
Mathematical "	32 00		
Drawing "	9 28		
		$3,726 91	
Rogers Building (alterations, etc.)		869 08	
Gymnasium "		791 41	
Walker Building "		779 69	
Replumbing Toilet Rooms, Eng'r'g B'ld'g		430 66	
Steam Fitting		362 00	
Engineering Building		312 27	
Pointing, etc., Engineering Building		188 95	
President's, Secretary's and Bursar's Offices		116 70	
Boiler Room		71 95	
Lunch Room		51 33	
Sundries		799 88	
			$8,500 83

General Expenses.

ɔtric Lighting: —			
Power Furnished	$169 49		
Wiring, etc.	338 28		
		$507 77	
ine Room Supplies: —			
Oil	$236 10		
Cotton Waste	53 19		
Sundries	70 67	359 96	
Insurance		2,354 91	
ionery and Office Supplies		1,248 33	
tage		876 00	
ınology Quarterly, Contribution to Publi-			
tion and Printing		807 78	
rance Examinations		731 92	
ell School of Design, 1883–92		720 66	
omas, Commissions, and Expense of Drills		558 29	
al Fees		525 00	
hing		396 80	
mination Books		377 50	
ress Charges, Teaming, etc.		374 95	
Amount carried forward		$9,839 87	

Amount brought forward . . .	$9,839 87	
Janitor's Supplies: —		
Brushes, Pails, Dusters, Soap, etc. . .	309 76	
Paints, Varnish, etc.	249 17	
Drafting on Buildings, Testing, etc. . .	247 70	
Books and Supplies for General Library . .	235 32	
Ice	175 64	
Window Shades	173 75	
Blackboards	145 50	
Towelling	134 10	
Furniture	115 37	
Window Glass	111 56	
Exhibit, State Medical Society . . .	104 69	
Union Safe Deposit Vaults, rent, 2 years .	100 00	
Safe, Bursar's Office	100 00	
Gymnasium Supplies	97 81	
Telephone and Telegraph Charges . . .	60 70	
Boston Electric Time Co.	33 00	
		$12,233 94

BOSTON, Dec. 5, 1892.

An examination of the accounts of the Treasurer of the Mas-achusetts Institute of Technology for the year ending Sept. 30, 892, has been made, and they are found to be correctly cast, id with proper vouchers. The ledger balances agree with the ial balance. We have verified the evidences of personal roperty held by the Institute.

FREDERIC W. LINCOLN,
CHARLES C. JACKSON,
JAMES P. TOLMAN,
Auditing Committee.

MASSACHUSETTS

STITUTE OF TECHNOLOGY.

ANNUAL REPORT

OF THE

PRESIDENT AND TREASURER,

DECEMBER 13, 1893.

JOHN WILSON AND SON,
University Press, Cambridge.
1893.

Members of the Corporation.

President.
FRANCIS A. WALKER.

Secretary.
FRANCIS H. WILLIAMS.

Treasurer.
GEORGE WIGGLESWORTH.

JOHN D. RUNKLE.
ALEXANDER H. RICE.
FREDERIC W. LINCOLN.
WILLIAM ENDICOTT, JR.
JOHN CUMMINGS.
THOMAS T. BOUVÉ.
AUGUSTUS LOWELL.
HOWARD A. CARSON.
CHARLES J. PAINE.
CHARLES FAIRCHILD.
DAVID R. WHITNEY.
LEWIS WM. TAPPAN, JR.
HENRY D. HYDE.
ALEXANDER S. WHEELER.
BENJAMIN P. CHENEY.
JAMES P. TOLMAN.
HOWARD STOCKTON.
ELIOT C. CLARKE.
NATHANIEL THAYER.
CHARLES F. CHOATE.
HENRY SALTONSTALL.
HENRY L. PIERCE.
HIRAM F. MILLS.
PERCIVAL LOWELL.
ARTHUR T. LYMAN.
CHARLES MERRIAM.
ARTHUR ROTCH.
THORNTON K. LOTHROP.
CHARLES C. JACKSON.
SAMUEL M. FELTON.
FRANCIS A. WATERHOUSE.
DESMOND FITZGERALD.
SAMUEL CABOT.
FRANCIS BLAKE.
CHARLES W. HUBBARD.
JAMES M. CRAFTS.
THOMAS L. LIVERMORE.
A. LAWRENCE ROTCH.
WILLIAM H. FORBES.
JOHN R. FREEMAN.
FRANK A. HILL.

On the Part of the Commonwealth.

HIS EXCELLENCY GOV. WILLIAM E. RUSSELL.
HON. WALBRIDGE A. FIELD, *Chief Justice of the Supreme Court.*
HON. JOHN W. DICKINSON, *Secretary of the Board of Education.*

Committees of the Corporation.

Executive Committee.

FRANCIS A. WALKER.
GEORGE WIGGLESWORTH. } *Ex Officiis.*

JOHN CUMMINGS. FRANCIS H. WILLIAMS.
HENRY SALTONSTALL. AUGUSTUS LOWELL.
ALEXANDER S. WHEELER.

Finance Committee.

WILLIAM ENDICOTT, JR. CHARLES C. JACKSON.
DAVID R. WHITNEY. NATHANIEL THAYER.
WILLIAM H. FORBES.

Committee on the Society of Arts.

HOWARD A. CARSON. HIRAM F. MILLS.
DESMOND FITZGERALD. FRANK A. HILL.

Committee on the Lowell School of Industrial Design.

PERCIVAL LOWELL. JOHN D. RUNKLE.
HENRY SALTONSTALL.

Auditing Committee.

FREDERIC W. LINCOLN. JAMES P. TOLMAN.
CHARLES C. JACKSON.

Committee on Nominations.

AUGUSTUS LOWELL. JOHN CUMMINGS.
ALEXANDER H. RICE. HOWARD STOCKTON.
FREDERIC W. LINCOLN.

Trustees of the Museum of Fine Arts.

ALEXANDER H. RICE. FRANCIS A. WALKER.
ARTHUR ROTCH.

Visiting Committees of the Corporation.

Department of Civil Engineering

HOWARD A. CARSON. ELIOT C. CLARKE.
CHARLES F. CHOATE. DESMOND FITZGERALD.
JOHN R. FREEMAN.

Departments of Mechanical Engineering and Applied Mechanics.

HIRAM F. MILLS. FRANCIS BLAKE.
DESMOND FITZGERALD. JAMES P. TOLMAN.
FRANK A. HILL.

Department of Mining and Metallurgy.

THOMAS T. BOUVÉ. THOMAS L. LIVERMORE.
CHARLES FAIRCHILD.

Department of Architecture.

ARTHUR ROTCH. THORNTON K. LOTHROP.
ELIOT C. CLARKE. JOHN R. FREEMAN.

Department of Physics and Electrical Engineering.

FRANCIS BLAKE. CHARLES W. HUBBARD.
A. LAWRENCE ROTCH.

Departments of Literature, History, and Political Economy.

ALEXANDER H. RICE. JOHN W. DICKINSON.
HENRY L. PIERCE. FRANCIS A. WATERHOUSE.

Department of Modern Languages.

FRANCIS A. WATERHOUSE. NATHANIEL THAYER.
ARTHUR ROTCH.

Department of Mathematics.

PERCIVAL LOWELL. HOWARD A. CARSON.
HOWARD STOCKTON. DESMOND FITZGERALD.

Departments of Chemistry and Biology.

SAMUEL CABOT. CHARLES C. JACKSON.
JAMES M. CRAFTS.

Department of Chemical Engineering.

ARTHUR T. LYMAN. SAMUEL CABOT.
HIRAM F. MILLS. CHARLES W. HUBBARD.

Department of Naval Architecture.

CHARLES J. PAINE. HOWARD STOCKTON.
WILLIAM H. FORBES.

To The Corporation of the Massachusetts Institute of Technology:

THE school year upon which I have now the honor to report has been one of mingled good and ill. There has been a large increase in the number of students, carrying the aggregate up to 1,157; a new course of instruction, that in naval architecture, has been successfully launched; the reputation and influence of the Institute have steadily widened, and there is reason to believe that every part of its work has been well done. On the other hand, no year in the history of the Institute has brought more distressing losses from the corps of instructors; and never, or not for many years at least, has the pressure of financial restriction been so hard and painful. The last-named feature of the situation is one which deserves the serious consideration of the members of the Corporation. It will soon be necessary, if indeed the time has not already come, for the friends of the Institute and the people of Boston and Massachusetts to decide whether this great school of industrial science, with its honorable record and its vast possibilities of future usefulness, shall be allowed to suffer serious and enduring injury and possibly irreparable disaster, from lack of pecuniary means. When it is remembered that the small and poor Republic of Switzerland, with its wide wastes of barren mountain, each year contributes $175,000 — a sum at least twice as large for all effective purposes as would be the same sum here in the United States — for the maintenance of the Polytechnicum at Zürich, can we believe that the Commonwealth and people of Massachusetts will permit an institution which has so completely proved its usefulness in the scientific and technical education of her sons, to languish from want of funds properly to sustain and progressively to enlarge its activities? The poverty of the Institute, it should be remembered, is due solely to its overwhelming success as an institution of learning. Enough has been bestowed upon it to have fairly

endowed a small institution of the second class, an ordinary college. The reason why its needs are so pressing is because it has become one of the largest institutions of the first class. Its needs are so great because it is itself so much needed.

The Graduating Class.

The school year of 1892–93 closed fortunately, on the 30th of May. Of the 129 graduating members of the class of '93, 25 graduated in Civil Engineering, 30 in Mechanical Engineering, 5 in Mining Engineering, 2 in Architecture, 8 in Chemistry, 41 in Electrical Engineering, 2 in Biology, 8 in Chemical Engineering, 2 in Geology, while 6 graduated from the department of General Studies.

The Entering Class.

The new year has witnessed a large increase in the numbers of the students in the school. The registration of this year, as by the catalogue now in press, amounts to 1,157, against 1,060 twelve months ago, a gain of 97. The following table exhibits the number of students in the school each year, from the opening of the Institute to the present time: —

Year.	No. of Students.	Year.	No. of Students.
1865–66	72	1880–81	253
1866–67	137	1881–82	302
1867–68	167	1882–83	368
1868–69	172	1883–84	443
1869–70	206	1884–85	579
1870–71	224	1885–86	609
1871–72	261	1886–87	637
1872–73	348	1887–88	720
1873–74	276	1888–89	827
1874–75	248	1889–90	909
1875–76	255	1890–91	937
1876–77	215	1891–92	1,011
1877–78	194	1892–93	1,060
1878–79	188	1893–94	1,157
1879–80	203		

Students by Classes.

The aggregate number of students for 1893–94 is divided among the several classes as follows:—

Graduate students, candidates for advanced degrees . .	2
Regular students, Fourth Year	146
" " Third "	158
" " Second "	207
" " First "	310
Special students	334
Total	1,157

Comparison with the corresponding figures of last year shows that there has been an increase among the regular students in the fourth year of 8, in the third year of 14, in the second year of 32, and among the special students of 48. There has been a decrease of 1 among the graduate students, candidates for advanced degrees, and of 4 in the regular students of the first year.

Assigning the special students to classes, according to the predominant studies pursued by them, we reach the following division of the whole body among the several years:

Class.	Regular.	Special.	Total.
Graduates of the M. I. T., candidates for advanced degrees . .	2		2
Fourth Year	146	49	195
Third Year	158	81	239
Second Year	207	168	375
First Year	310	36	346
Total	823	334	1,157

Statistics of Examinations.

Of the 1,157 students of the present year, 456 were not connected with the school in 1892–93; 25 had been connected with the Institute at some previous time, and returned to

resume their places in the school; 42 were admitted provisionally without examination; 25 were admitted by examination as special students; 80 were admitted on the presentation of diplomas or certificates from other institutions.

Excluding from consideration those who were admitted but have not in fact entered the school, 68 in number, the following was the final result of the examinations held in June and September: —

Admitted clear	191	
" on one condition	53	
" on two conditions	29	
" on three conditions	11	284
Rejected		44
		328

Examinations at Distant Points.

In addition to the entrance examinations held at Boston in June and September, examinations were also conducted in June at Belmont (Cal.), Chicago, Cincinnati, Cleveland, Denver, Detroit, Easthampton (Mass.), Exeter (N. H.), Montreal, New York, Philadelphia, Pittsburgh, Poughkeepsie, St. Louis, St. Paul, Toronto, and Washington.

Residence of Students.

Forty States of the Union, besides the District of Columbia and the Territories of Utah and New Mexico, are represented on our list of students. Of the total number of 1,157, 665 are from Massachusetts, or 57.5% of the whole; 136 are from other New England States; 356 are from outside New England, of whom 31 are from foreign countries.

The following table shows the number of students of each specified class, from each State or foreign country : —

States.	Candidates for Advanced Degrees.	Fourth Year.	Third Year.	Second Year.	First Year.	All Regular Students.	Special Students.	Total.
Alabama				1		1	1	2
Arkansas		1				1		1
California		2	4	2		8	7	15
Colorado		1	2		1	4	1	5
Connecticut		6	4	5	9	24	6	30
Delaware		1		1	2	4		4
Dist. Columbia		2		2	1	5	2	7
Florida			1	1		2	1	3
Georgia							3	3
Idaho		1						1
Illinois		5	3	12	8	28	11	39
Indiana		3	1		1	5	1	6
Iowa		2	4	1	1	8	5	13
Kansas							1	1
Kentucky		2	1	1	3	7	4	11
Louisiana							3	3
Maine		3	5	6	10	24	12	36
Maryland				1		1	3	4
Massachusetts	2	80	91	123	199	495	170	665
Michigan			1	1	2	4	3	7
Minnesota		4	3	1	2	10	1	11
Missouri		1	1	3	4	9	8	17
Montana					2	2		2
Nebraska			2	1		3		3
Nevada		1				1	1	2
N. Hampshire		5	5	8	10	28	4	32
New Jersey		1				1	5	6
New Mexico			1	1		2		2
New York		6	6	11	15	38	14	52
Ohio		3	5	7	9	24	21	45
Oregon							1	1
Pennsylvania		4	7	5	10	26	5	31
Rhode Island		4	7	3	9	23	10	33
South Carolina		1		1		2	1	3
Tennessee							1	1
Texas					3		3	6
Utah							2	2
Vermont					2	2	3	5
Virginia							3	3
Washington							1	1
West Virginia		1				1		1
Wisconsin		1		3	2	6	5	11
Foreign Countries.								
Belgium				1		1		1
Bulgaria		1				1		1
Cent'l America		1				1		1
Cuba					1	1		1
England		1				1		1
France							1	1
Germany				1		1	1	2
Hawaiian Isl'ds							2	2
Holland			2			2		2
Ireland			1				1	1
Japan					1	1		1
Mexico							1	1
N. Brunswick			1			1		1
New So. Wales							1	1
Ontario					3	3	1	4
Porto Rico							1	1
Quebec		1		1	3	5		5
Scotland		1				1	1	2
Spain							1	1
Venezuela							1	1
Total	2	146	158	207	310	823	334	1,157

A table showing the number of students in each year from and including 1887, coming from each State or Territory and from each foreign country, may not be without interest and instruction: —

	1887.	1888.	1889.	1890.	1891.	1892.	1893.
States.							
Alabama	..	..	1	..	2	4	2
Arkansas	3	2	2	3	3	2	1
California	9	13	10	14	19	14	15
Colorado	2	2	6	4	7	7	5
Connecticut	29	28	36	31	30	27	30
Delaware	..	..	..	1	..	2	4
Dist. of Columbia	4	9	9	7	4	4	7
Florida	..	..	2	3	3	4	3
Georgia	2	1	1	2	2	3	3
Idaho	..	..	..	..	1	1	1
Illinois	29	37	33	34	32	40	39
Indiana	..	1	3	6	3	5	6
Iowa	3	6	4	9	10	10	13
Kansas	..	..	..	2	2	1	1
Kentucky	2	3	4	4	8	7	11
Louisiana	..	2	4	8	5	2	3
Maine	24	26	30	29	27	39	36
Maryland	2	4	4	7	7	6	4
Massachusetts	429	494	533	517	565	603	665
Michigan	10	12	13	16	13	10	7
Minnesota	6	8	10	12	13	13	11
Missouri	5	7	8	8	12	13	17
Montana	..	..	..	1	..	..	2
Nebraska	4	2	1	1	1	4	3
Nevada	..	..	..	1	3	3	2
New Hampshire	19	24	21	23	24	29	32
New Jersey	11	8	13	11	16	11	6
New Mexico	..	2	..	..	1	2	2
New York	35	31	25	40	40	50	52
North Carolina	..	1	2	1	1	1	..
Ohio	21	23	35	33	33	39	45
Oregon	..	1	2	1	1	2	1
Pennsylvania	18	18	23	22	26	25	31
Rhode Island	19	22	22	21	26	24	33
South Carolina	1	..	1	2	4	1	3
South Dakota	1	1	1	..	..	..	..
Tennessee	2	3	5	3	4	1	1
Texas	1	2	..	1	2	5	6
Utah	..	..	..	..	..	1	2
Vermont	7	5	4	4	5	4	5
Virginia	5	4	6	5	6	4	3
Washington	1	..	2	2	3	3	1
West Virginia	..	..	2	2	2	2	1
Wisconsin	5	7	9	10	7	9	11
Wyoming	..	1	..	..	..	..	..
Foreign Countries.							
Argentine Rep.	..	..	..	2	..	..	..
Belgium	..	..	..	..	..	1	1
Brazil	1	2	2	2	4	..	..
Bulgaria	..	..	1	1	1	1	1
Central America	..	..	..	..	1	1	1
Colombia	..	..	1	..	2	..	..
Cuba	..	..	..	..	..	..	1
England	..	..	..	2	1	1	1
France	..	..	1	1	1	1	1
Germany	..	..	..	..	..	..	2
Greece	..	1	..	..	..	..	..
Guatemala	1	1	1	..	..	1	..
Hawaiian Islands	..	1	1	4	4	2	2
Holland	..	..	..	..	2	2	2
Ireland	1	1	1	1	..	..	1
Japan	1	..	1	4	3	1	1
Mexico	..	..	1	1	1	1	1
New Brunswick	..	1	1	1	2	1	1
New South Wales	..	..	..	..	1	1	1
Nova Scotia	..	..	2	2	1	..	..
Ontario	1	2	1	1	2	2	4
Peru	1	2	1	3	1	..	..
Porto Rico	1	2	2	2	1	..	1
Quebec	2	1	1	4	4	5	5
Scotland	..	1	1	3	2	1	2
Spain	..	..	..	..	..	1	1
Trinidad	1	1	1	1	1	..	..
Turkey	1	1	2	1	2	1	..
Venezuela	..	..	..	..	1	..	1
Total	720	827	909	937	1,011	1,060	1,157

Residence of Massachusetts Students.

It has been said that 57.5 per cent of our students are from Massachusetts. All the counties of the State, except the small counties of Dukes and Nantucket, send students to the Institute. One hundred and fifteen cities and towns are borne on the lists, one more than last year. The first

column of the following table shows the number of cities and towns in each county sending pupils to the Institute; the second column gives the aggregate number from each county. It appears that Suffolk sends 201 and Middlesex 192 pupils; Essex comes third, with 81; Norfolk fourth, with 78.

County.	No. of Towns.	No. of Students.	County.	No. of Towns.	No. of Students.
Barnstable . . .	4	7	Hampshire . . .	3	3
Berkshire . . .	5	13	Middlesex . . .	30	192
Bristol	6	21	Norfolk	17	78
Essex	17	81	Plymouth . . .	12	35
Franklin	4	6	Suffolk	4	201
Hampden . . .	5	14	Worcester . . .	8	14
Total	41	142	Total	115	665

The following is a list of the towns, forty-one in number, which send four or more students to the Institute:—

Boston	186	Springfield . .	9	Gloucester . . .	5
Newton	30	Watertown . .	8	Medford . . .	5
Cambridge . .	29	Brockton . . .	7	Rockland . . .	5
Brookline . . .	25	Melrose . . .	7	Weymouth . .	5
Newburyport . .	19	Pittsfield . . .	7	Arlington . . .	4
Lynn	16	Plymouth . . .	7	Barnstable . . .	4
Somerville . . .	14	Reading . . .	7	Concord . . .	4
Hyde Park . .	13	Salem	7	Danvers . . .	4
Lowell	13	Taunton . . .	7	Dedham . . .	4
Chelsea	12	Wakefield . . .	7	Fitchburg . . .	4
Waltham . . .	12	Andover . . .	6	Mansfield . . .	4
Framingham . .	11	Natick	6	Marlboro' . . .	4
Lawrence . . .	10	New Bedford . .	6	Wellesley . . .	4
Malden	9	Quincy	6		

The following table exhibits, for ten years, the distribution of the total number of students among two classes: first, those students whose names are found upon the catalogue of the year preceding; and secondly, those students whose names appear as new names upon the catalogue of the year to which the statement relates: —

Year.	(1) Total No. of Students.	(2) No. of Students in the Catalogue of the previous year who remain in the Institute.	(3) No. of New Students entering before issue of Catalogue.	(4) Of those in column (3) the following number are regular first-year Students.	(5) No. of New Students not of the regular first-year class.
1884–85	579	311	268	186	82
1885–86	609	369	240	177	63
1886–87	637	379	258	190	68
1887–88	720	396	324	229	95
1888–89	827	465	362	245	117
1889–90	909	557	352	255	97
1890–91	937	572	365	234	131
1891–92	1,011	624	387	258	129
1892–93	1,060	618	442	303	139
1893–94	1,157	701	456	301 *	155

It appears from the foregoing that the number of students remaining over from last year to this has been increased by eighty-three, while the number registered for the first time is larger by fourteen, making the total increase, as stated, ninety-seven. The effect of the hard times has therefore been, not to decrease, but rather largely to increase, the attendance at the Institute. This is all the more remarkable in view of the large number of technical schools springing up all over the land, and of technical departments newly added to many of the old-fashioned colleges and universities.

Ages of Students on Entrance.

The next table exhibits the ages of our students upon entrance, after taking out those who are repeating the first year, and seventeen of unusual ages. These deductions leave two hundred and eighty-four as the number of students whose ages have been made the subject of computation. The results appear in the following table, in comparison with the corresponding results of 1892–93.

* In addition nine students are repeating the first year.

Period of Life.	1892–93.		1893–94.	
	Half-year Groups.	Yearly Groups.	Half-year Groups.	Yearly Groups.
16 to 16½ years	3	–	1	–
16½ to 17 "	5	8	2	3
17 to 17½ "	18	–	23	–
17½ to 18 "	36	54	56	79
18 to 18½ "	49	–	48	–
18½ to 19 "	55	104	47	95
19 to 19½ "	58	–	51	–
19½ to 20 "	32	90	30	81
20 to 20½ "	25	–	9	–
20½ to 21 "	7	32	9	18
21 to 22 "	9	9	8	8
	297	297	284	284

From the foregoing tables it appears that the average age of the two hundred and eighty-four students taken for this comparison is eighteen years, nine months, or one month less than last year.

In this connection it may be interesting to note the ages at graduation of the class leaving us in May. The one hundred and twenty-nine members of the class were distributed among the several periods of life as follows: —

Under 20	1
Between 20 and 20½	3
" 20½ and 21	8
" 21 and 21½	14
" 21½ and 22	34
" 22 and 23	38
" 23 and 24	14
24 and over	17
	129

Proportion of Regular and of Special Students.

The following table exhibits both the absolute number of regular and of special students, as by the catalogue of each

successive year since 1882, and the proportion existing between these two classes:—

Year.	No. of Regular Students.	No. of Special Students.	Total No. of Students.	Percentage.	
				Regular.	Special.
1882–83 . . .	219	149	368	60	40
1883–84 . . .	272	171	443	61	39
1884–85 . . .	368	211	579	64	36
1885–86 . . .	415	194	609	68	32
1886–87 . . .	442	195	637	69	31
1887–88 . . .	520	200	720	72	28
1888–89 . . .	590	237	827	71	29
1889–90 . . .	652	257	909	72	28
1890–91 . . .	658	279	937	70	30
1891–92 . . .	706	305	1,011	70	30
1892–93 . . .	774	286	1,060	73	27
1893–94 . . .	823	334	1,157	71	29

Women as Students at the Institute.

The number of women pursuing courses with us is forty-six as against forty-one last year. Of this number, eight are graduates of colleges. Of the total number, two are regular students of the fourth year; three of the third year; four of the second year. Thirty-seven are special students. Of the nine regular students of the upper classes, five take Course IV., Architecture; one, Course VII., Natural History; two, Course VIII., Physics; one, Course XII., Geology. Of the special students, two devote themselves to Architecture; six to Chemistry; four to Physics; nineteen chiefly to Biology and allied subjects; and six to English, History, or Political Science.

Graduates of Other Colleges.

The number of students who are graduates from this and other institutions shows a very marked and gratifying increase over last year. Seventy-nine graduates of institutions conferring degrees are now included in our list of students. Of these, eleven are our own graduates, of whom two are pursuing studies as candidates for advanced degrees; sixty-nine are

graduates of other institutions, pursuing courses of study with us, either as regular or as special students. One of these is also a graduate of the Institute. Nineteen are graduates of Harvard University; four of Yale University; and three each of Williams and Smith Colleges; two each of Johns Hopkins University, the University of Minnesota, and Iowa Agricultural College; while the following institutions, universities or colleges, are represented on our list by a single graduate each, — Trinity College (Dublin), Drake University, Vassar, Brown, Dartmouth, Georgetown, Göttingen, Kenyon, Holy Cross, Pennsylvania State College, Smith, Charleston, Caracas, Cornell, Delaware, Michigan State Agricultural College, Chicago, Havana, Straight, Iowa State College, Harvard Annex, University of the city of New York, North Western University, Bowdoin, Centre, Lafayette, Marietta, Oberlin, Ogden, Robert, Wellesley, The Michigan Mining School, The National Institute, and Worcester Polytechnic.

The candidates for advanced degrees are Messrs. J. A. Meyer, Jr., of the class of 1891, in Architecture, and F. H. Fay of the class of 1893, in Civil Engineering. Messrs. W. W. Carter and H. L. Clapp of the last graduating class, in Chemical Engineering, and Mr. N. R. Craighill of the same class, in Mechanical Engineering, have returned to take an additional year of study as candidates for the bachelor's degree in Electrical Engineering. Mr. G. W. Stose of the class of 1893, in Civil Engineering, is a candidate for the degree in Geology. Messrs. C. H. Alden, Jr., of the class of 1890, H. B. Clement of the class of 1891, P. A. Hopkins and G. H. Ingraham of the class of 1892, have returned for special advanced work in Architecture. Mr. R. Selfridge, of the class of 1892, in General Studies, is also a special student in Architecture.

Of the seventy-seven, not candidates for advanced degrees, thirty-eight are regular students, — namely, thirteen in the fourth year; thirteen in the third year; nine in the second year; three in the first year; the remaining thirty-nine are special students. Of the thirty-five graduates who

are regular students in the three upper classes, five take Civil Engineering; one, Mining Engineering; three, Mechanical Engineering; eleven, Architecture; two, Chemistry; thirteen, Electrical Engineering.

The Courses of Instruction.

The following table presents the numbers of the regular students in the third and fourth years.

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Electrical Engineering.	Biology.	Physics.	General Course.	Chemical Engineering.	Sanitary Engineering.	Geology.	Naval Architecture.	Total.
4th Year Class .	23	31	4	16	12	35	1	3	5	13	3	..	..	146
3d " " .	22	37	6	14	13	38	1	3	5	10	3	2	4	158
2d " " .	33	29	12	20	14	68	2	4	9	8	4	..	4	207
Total . . .	78	97	22	50	39	141	4	10	19	31	10	2	8	511

The following table shows the figures of the total line in the foregoing table, in comparison with the corresponding figures for the next nine preceding years: —

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering and Metallurgy.	Architecture.	Chemistry.	Electrical Engineering.	Biology.	Physics.	General Course.	Chemical Engineering.	Sanitary Engineering.	Geology.	Naval Architecture.	Total.
1884	29	54	28	9	20	30	1	1	3	..	..	..	..	175
1885	44	74	26	10	23	41	4	1	5	..	..	..	..	228
1886	45	75	19	13	24	52	4	2	8	..	..	..	..	242
1887	50	89	16	18	23	61	5	6	14	..	..	..	..	282
1888	71	100	12	21	28	74	4	5	12	11	..	..	..	338
1889	79	99	14	30	29	91	9	5	12	14	6	..	..	388
1890	79	95	18	27	27	105	11	4	13	18	7	3	..	407
1891	81	104	17	33	23	108	11	5	19	28	9	3	..	441
1892	76	106	19	37	35	112	9	5	16	34	5	3	..	457
1893	78	97	22	50	39	141	4	10	19	31	10	2	8	511

It will appear from the foregoing table that the course in Electrical Engineering remains the largest of the courses of the school. The courses in Mechanical and Civil Engineering follow in the order in which I name them. These three courses together embrace three hundred and sixteen of the five hundred and eleven regular students candidates for the degree in the three upper classes. In the case of Course IV., Architecture, the number of regular students fails to measure the importance of the department to the school, inasmuch as that course embraces a considerable number of college graduates and of young men who have had experience as draughtsmen and assistants in architects' offices, who are allowed to enter the department as special students, to get as nearly as possible what they require without passing through the full course. Thus, the number of special students in Architecture in the three upper classes the present year is sixty-nine, which, added to the fifty regular students, makes the total number one hundred and nineteen. The Chemical and Biological courses also contain considerable numbers of special students, often of advanced grade, some of them teachers or persons who have been engaged in professional practice. I repeat my remark of last year, that in regard to the courses having a very small number of students, the figures above do not fairly represent the real importance of these courses to the Institute. Thus, the Physics course, being a pure science course, has never had, and is not expected to have, a large number of students. Yet that course has always been a power for good in the Institute; some of our strongest men have graduated from it; and the influence of the instruction given in it has always had a great effect upon the technical courses of the school.

The following table exhibits the number of persons who have graduated within each of the several courses at each succeeding year since the first diplomas were conferred: —

Year.	Civil Engineering.	Mechanical Engineering.	Mining Engineering.	Architecture.	Chemistry.	Metallurgy.	Electrical Engineering.	Natural History or Biology.	Physics.	General Course.	Chemical Engineering.	Sanitary Engineering.	Geology.	Total.
1868	6	1	6	..	..	..	..	..	..	1	..	..	..	14
1869	2	2	..	..	1	..	..	..	..	..	..	..	..	5
1870	4	2	2	..	1	..	..	..	..	1	..	..	..	10
1871	8	2	5	..	2	..	..	..	..	..	..	..	..	17
1872	3	1	5	..	3	..	..	..	..	..	..	..	..	12
1873	12	2	3	1	7	..	..	..	..	1	..	..	..	26
1874	10	4	1	1	..	..	..	..	..	2	..	..	..	18
1875	10	6	6	1	1	..	..	..	1	2	..	..	..	27
1876	12	9	7	..	5	1	..	2	3	4	..	..	..	43
1877	12	6	8	4	2	..	..	..	..	..	..	..	..	32
1878	8	2	2	3	3	..	..	..	..	1	..	..	..	19
1879	6	8	3	1	3	..	..	1	1	..	..	..	..	23
1880	3	..	3	..	1	..	..	..	..	1	..	..	..	8
1881	3	5	6	3	8	..	..	1	..	2	..	..	..	28
1882	2	5	5	3	6	..	..	1	1	1	..	..	..	24
1883	3	7	5	1	3	..	..	..	..	..	..	..	..	19
1884	5	6	13	..	12	..	..	..	..	..	..	..	..	36
1885	4	6	8	2	4	..	2	..	..	1	..	..	..	27
1886	9	23	7	1	7	..	10	1	..	1	..	..	..	59
1887	10	17	8	1	9	..	8	1	1	3	..	..	..	58
1888	11	25	4	5	10	..	17	3	1	1	..	..	..	77
1889	15	23	5	3	8	..	17	1	1	2	..	..	..	75
1890	25	27	3	5	13	..	18	3	2	6	..	..	..	102
1891	17	26	4	6	11	..	23	3	3	1	7	..	1	102
1892	22	26	4	12	7	..	36	6	1	7	4	6	1	132
1893	25	30	5	2	8	..	41	2	..	6	8	..	2	129
Total	247	271	128	55	135	1	172	25	15	44	19	6	4	1,122
Deduct names counted twice														5
Net total														1,117

The Earlier Choice of Courses.

I spoke in my last Annual Report of a very important change in the policy of the school, by which the students were to make choice of their courses at the opening of the second term of the first year, instead of at the opening of the second year; and I there gave the grounds upon which it was anticipated that benefit would result to the students and to the school from this new departure. I am now able to report,

after the trial of a single year, that the system is beyond doubt successful, although greater benefit will probably be realized from it the coming year than during the year in which it was first put into operation, and that with comparatively little preparation.

Classification of Special Students.

Our special students, of course, cannot be classified systematically, but the following table exhibits the number of such students pursuing each particular branch of study: —

Applied Mechanics	56	History	94
Architecture	69	Language	164
Biology	35	Mathematics	191
Chemistry	118	Mechanical Engineering	83
Civil Engineering	39	Mining Engineering	15
Drawing	171	Physics	174
Electrical Engineering	36	Political Science	54
English	120	Shopwork	75
Geology	34		

It may be of interest to note the number of students, either regular or special, pursuing certain leading branches of study, in each of the four years, as follows: —

	First Year.	Second Year.	Third Year.	Fourth Year.	Total.
Mathematics	345	289	168	55	857
Chemistry	381	77	57	36	551
English	331	266	17	17	631
French	240	76	38	16	370
Physics	..	316	216	77	609
German	65	213	125	7	410
Shopwork	14	142	50	46	252

Classes from the Boston Normal School of Gymnastics.

Toward the close of the last school year, as the result of negotiations between the Executive Committee of the Institute and Mrs. Mary Hemenway, whose large philanthropic

plans have embraced the maintenance of a normal school in Boston for the training of teachers to have charge of instruction in physical culture, an agreement was entered into by which the pupils in both years of the school referred to are to receive their instruction in Physics, Chemistry, and Biology, as special students in the Institute of Technology. These students, who number in all fifty-two, are, however, not embraced in the catalogue of the Institute; nor are they included in the statistics of attendance, etc., which I have already given. The instruction of these classes in Physics has been committed to Mr. Derr; Mr. Bardwell conducts the classes in Chemistry; while Professor Sedgwick and Dr. Hough have charge of their work in the Biological Laboratory. It is believed that by this arrangement, which is necessarily of a temporary character, the Institute will both confer and receive benefit.

Five-Year Courses.

The number of students in the five-year courses is shown in the following table, with their distribution by years and by courses: —

Year.	Total.	Course.										Course, Undetermined.
		I.	II.	III.	IV.	VI.	VII.	IX.	X.	XI.	XII.	
First	9	..	..	..	..	..	..	..	..	..	..	9
Second . . .	14	4	2	1	..	4	..	2	..	1	..	..
Third . . .	10	..	3	1	1	3	1	..	..	..	1	..
Fourth . . .	9	1	2	..	3	..	..	..	2	1	..	..
Fifth . . .	7	..	2	..	4	1	..	..	..	..	..	..
	49	5	9	2	8	8	1	2	2	2	1	9

Changes in the Faculty and in the Corps of Instructors.

Last year I announced the loss of two members of the Faculty,— one, Professor Létang, by death; the other, Professor Luquiens, by resignation. This year it is my painful duty to report the loss of three members of the Faculty, — one by death and two by resignation.

On the 26th of April, 1893, Prof. Lewis M. Norton, in charge of the department of Industrial Chemistry and of the course in Chemical Engineering, died, after a brief illness, of pneumonia, at his home in Auburndale. Professor Norton's death constitutes one of the severest blows which the Institute has ever sustained. A chemist of reputation and experience, he was pre-eminently a teacher; and research and practice had for him their chief value as they enabled him to build up new courses of technical instruction in the school.

Dr. Norton was an assistant at the Institute from 1875 to 1877; during the two following years he studied abroad, taking his doctor's degree in Göttingen in 1879. For the three years next succeeding he was chief chemist in one of the largest manufacturing works of New England, but gladly availed himself of a call to the Institute as an instructor, in 1882. The following year he became Assistant Professor, and in 1885, Associate Professor, having charge of the laboratories both of organic and of industrial chemistry. Of the latter charge he was relieved in 1891, being thus enabled to concentrate his energies upon his chosen field of industrial chemistry, in which he soon gained a degree of success which has only been surpassed in a few of the older institutions of Europe. Between 1886 and 1888, Professor Norton rendered an inexpressible service to the Institute of Technology and to the general cause of technical instruction in the United States by proposing and arranging a new course of instruction, appropriately termed Chemical Engineering, which was, after long discussion and deliberation, adopted by the Faculty and opened to students in 1888. To the development of this

course Professor Norton applied himself with unwearying attention, so that at the time of his lamented death he had brought it to rank with the most highly organized, best integrated and most efficient courses of instruction in our school.

For the work of conducting the two courses with which he was thus strongly associated, — namely, Industrial Chemistry (the application of chemistry to manufactures), and Chemical Engineering (the application of mechanical engineering to the problems of the chemical manufactures), — Professor Norton had pre-eminent qualifications, so much so that since his death the name of no single person in this country has suggested itself to the Faculty as that of a full and competent successor. As a chemist conducting investigations of a purely scientific character, he had his superiors; but in the qualifications for building up and conducting the two courses referred to, he was without a peer.

I should do injustice to the subject if I did not add a brief tribute to the sincerity, purity, earnestness, and kindliness of Professor Norton's character, his deep devotion to the Institute, and his unflagging interest in the welfare of all the students under his charge. Indeed, his interest in our students was not limited by the bounds of his own courses. For several years he had practically the entire charge of the subject of free scholarships at the Institute; and in the discharge of this difficult duty he took the greatest care and pains. He personally knew every student in the school who was an applicant for a scholarship, and entered deeply into the needs and feelings of every man who came to him for such a purpose. As a member of the Faculty Dr. Norton was earnest and zealous, punctilious without being narrow, progressive while yet holding strongly to all the best traditions of the Institute.

During the past summer Prof. Charles H. Levermore resigned the chair of History to accept the principalship of the Adelphi Academy in Brooklyn; and Prof. George R. Carpenter, in charge of the department of English, left us to

accept a professorship of Literature in Columbia College, New York. Professor Levermore came to us in 1888, from the University of California, and during the five years of his connection with the Institute has had a most distinguished career. A ripe historical scholar, a profound thinker, a teacher of rare powers and of great command over his pupils, his loss must be deeply felt in the immediate future of the school. Professor Carpenter came to us in 1890 from Harvard University, and during the three years of his stay here, built up an admirable system of instruction in English. Broad, liberal, and tolerant, a graceful scholar wholly devoid of intellectual snobbishness, deeply interested in the work he had undertaken, the results of his labors here will not be lost, though we may lament that he is no longer personally to carry out the excellent system he had inaugurated.

No attempt has as yet been made to fill Dr. Norton's place in the Faculty. Professor Drown has for the year assumed the charge of the instruction before given by Professor Norton; Dr. Frank H. Thorp has been appointed instructor in Industrial Chemistry, and will enter upon the discharge of his duties at the beginning of the second term; and a considerable number of highly experienced lecturers have been secured to give courses in their respective specialties.

Professor Levermore's chair has also been left vacant for the year, owing to the lateness of the time at which his resignation was received. Assistant Professor Currier assumed the charge of the instruction in History at the opening of the year, and has shown excellent capacity in the emergency thus created. An additional instructor, Dr. Edson L. Whitney, of Harvard University, has been appointed; and it has been sought by means of distinguished lecturers, called in from the outside, to prevent the instruction in this important department from suffering through the departure of Professor Levermore. Mr. John Fiske is now delivering an inspiring course of lectures upon Early American History to the students of the second year; Mr. A. Lawrence Lowell, of Boston, is to

give in the second term a course on the Political Institutions of Europe to the students of the first year; and Prof. John F. Jameson, of Brown University, is in the same term to conduct a course on Advanced Constitutional History, for the benefit of the classes in Course IX. I esteem the Institute fortunate in that, through the arrangements thus described, we shall be able the present year to keep our instruction in History on a high plane.

There has been less delay in filling the chair left vacant by Professor Carpenter's resignation, Mr. Arlo Bates having, to our great satisfaction, accepted the position of Professor of English. Professor Bates entered upon his new duties in September. The Faculty are to be congratulated upon the accession of a colleague so widely and variously accomplished. The Corporation may feel assured that his high abilities, his long and thorough training in journalism and in literary work, and his earnest devotion to the task he has undertaken will command complete success.

The Corps of Instructors.

The catalogue of 1893–94 shows the number of instructors of all grades to be one hundred and seventeen, inclusive of those concerned with the mechanic arts, but exclusive of those who are announced as lecturers for the year only. The addition of these raises the total to one hundred and forty-four. The following table shows the distribution among the several classes of instructors, with the gain or loss since last year:—

	1892–93.	1893–94.
Professors	16	19
Associate Professors	11	6
Assistant Professors	11	14
Instructors	41	52
Assistants	30	26
Lecturers	16	27
Total	125	144

The instructing staff for the year 1893–94 is distributed as follows among the several departments of the school: —

	Civil Engineering.	Mechanical Eng. and App. Mechanics.	Mining Engineering and Metallurgy.	Naval Architecture.	Architecture.	Chemistry.	Physics and Electrical Engineering.	Biology, Zoölogy, Etc.	Mineralogy, Geology, and Geography.	English History and Political Science.	Language.	Mathematics.	Drawing and Descriptive Geometry.	Mechanic Arts.	Military Tactics.
Professors . . . . . (19)	1	1	1	1	1	2	2	1	1	2	1	4	..	..	1
Associate Professors . (6)	3	1	1	..	1	..	..	..	..	..	..	..	..	..	..
Assistant Professors . (14)	..	3	..	..	1	2	1	..	1	1	2	2	1	..	..
Instructors . . . . . (52)	2	3	1	1	1	12	8	2	1	4	4	7	3	3	..
Assistants . . . . . (26)	4	8	..	..	1	4	1	1	1	..	..	..	3	3	..
Total . . . . (117)	10	16	3	2	5	20	12	4	4	7	7	13	7	6	1
Lecturers . . . . . (27)	1	..	1	..	4	8	5	3	..	5	..	..	..	..	..
Total . . . . (144)	11	16	4	2	9	28	17	7	4	12	7	13	7	6	1

The accession of Mr. Meyer to the Modern Language Department has allowed a certain reduction to be effected in the size of the class-sections and a certain increase of optional advanced work. The sections of this department are, however, too large, and it is greatly to be desired that the instructing staff should be still further increased. Assistant Professor Vogel is this year on a leave of absence pursuing studies at the University of Heidelberg. If, on his return, it should be found practicable to retain the present body of teachers entire, we shall be able to add greatly to the usefulness of our Modern Language Department, especially on the German side.

The library of the department has been increased during the year by some accessions, notably that of the great German Encyclopædia of Ersch and Gruber, which numbers

one hundred and forty volumes already published, and that of the Century Dictionary; but many more works are needed to furnish both teachers and students with the best books of reference in French, German, Italian, and Spanish; and it is hoped that the financial means of the Institute may soon allow a considerable increase of the sum assigned to this object.

A gratifying sign of the increased interest of the students in the study of modern languages the present year has been the formation of a French society, which has already taken a strong hold upon its large membership, and promises to be very useful in giving opportunities for practice in speaking. So successful has been this society that a similar organization is now forming among the students of German. In the regular school exercises in the French language an effort has been made during the year on which I am now reporting to give the students, besides facility in translation, a better foundation in grammar and larger opportunities for hearing the spoken language. Questions have been asked and answered in French to a greater extent than ever before; and these efforts on the part of the teachers have generally received a cordial response from the pupils. This procedure calls for much more activity on the part of the teacher, and makes it increasingly desirable to obtain a further subdivision of the sections. In German the progress of the work of instruction has been even more satisfactory, by reason of the fact that the students of this language — that is, with the exception of four out of eighteen sections — begin this study at the Institute; and therefore all are from the outset taught in the same way, and well taught, whereas in French all the students, with the exception of the four sections referred to, have had their preliminary French training in a great variety of schools, according to a great variety of methods, and not infrequently with teachers not of the highest accomplishments.

It is gratifying to feel assured that within the immediate future we may look for a marked improvement of our modern

language instruction at the Institute, not merely through our own efforts, but also through marked advances to be made in the preparatory schools. The movement for the improvement of the secondary schools of the United States, the high schools and endowed academies, which was inaugurated a few years ago by the National Association of School Superintendents, and to which President Eliot of Harvard University has largely contributed, seems destined to produce early results of high value, bringing pupils to the colleges and technical schools much more fully and more thoroughly prepared. Professor van Daell has been a member of the Committee on Modern Languages dealing with this subject.

Perhaps the most interesting thing in connection with the English Department is the success of the experiment of co-operation, whereby the technical essays and memoirs of the scientific courses come to the instructors in English for criticism of diction and form. This method of work is found to have many advantages. It leaves the heads of the several departments free to lay all their stress upon the technical criticism which they alone are qualified to give; it enforces the absolute necessity of correct language and clearness of style for exact scientific statement; while it gives to the student an opportunity of testing practically his command of accuracy of expression in the line of his especial branch, and keeps distinct in his mind the difference between criticism of his scientific knowledge and of his manner of expressing it. Under this system, students take more pains in preparing their technical papers, with the obvious result that they gain not only facility and clearness of expression, but accuracy and sharpness of thought as well.

The most important change in the Mathematical Department has been the rearrangement of the general courses consequent upon the advance in entrance requirements referred to in the last Annual Report. The time assigned to first-year Mathematics has heretofore included in the first term sixty hours of recitations and one hundred and twenty of preparation, equally divided between Algebra

and Geometry, while in the second term seventy hours of exercise and one hundred and forty of preparation have been devoted to Plane and Spherical Trigonometry. By the new requirements, either Algebra or Solid Geometry must be presented for admission. In utilizing the time thus left free, the department has been able to effect a long-desired rearrangement of the general mathematical work, which has heretofore extended to the middle of the third year in all engineering courses. The time gained, with the omission (except from Course I.) of Spherical Trigonometry, renders it possible to transfer Analytic Geometry from the second year to the first, and, so far as can now be anticipated, Integral Calculus from the third year to the second. The engineering students will thus acquire by the end of the second year all the mathematical preparation essential for their work in Applied Mechanics and the various technical subjects dependent upon Calculus.

It is probable also that a part of the time set free in the third year may in several of the departments be devoted to a course in Solid Analytic Geometry, — a subject of obvious importance, which has heretofore been offered only to students in the course in Physics. The changes outlined above permit an increase in the time heretofore available for the brief course in Analytic Geometry taken by students in Biology and in General Studies, and also an important differentiation of the mathematical instruction offered to students in Chemistry, enabling them to finish by the middle of their second year briefer courses in Analytic Geometry and Calculus, in preparation for the study of Theoretical Chemistry. The department has been enabled, by a special appropriation, to place in its library a considerable number of the admirable models manufactured by Brill of Darmstadt.

Military Science and Tactics.

The greatest relative change in any department of the Institute is doubtless to be found in that of military science and tactics. Heretofore the time allotted has been employed almost exclusively in drill. Lieutenant Hawthorne has taken an enlarged view of his duties under the Act of Congress, July 2, 1862, which requires this class of instruction to be given in all colleges receiving aid from the general government. He believes that the time should not be used wholly in a continuation of high-school drill, but that a portion should be employed in giving the students a clear conception of the simple principles of the art of war and a knowledge of the military history of our own country; above all, a thorough acquaintance with the duties of company officers, regarding recruiting and the care of men, responsibility for stores, equipments, and supplies, the routine of camp, marches, and the necessary discipline of military life. In this view taken by Lieutenant Hawthorne, I heartily concur. If the graduates of the Institute of Technology should ever be called upon to put to use in their country's service the information and training which they have acquired in this department, it will be almost wholly as officers, called upon in an emergency to assist in bringing troops into the field, and providing for their early organization and discipline. This was the work for which the resources of the nation were most painfully inadequate in 1861; and the same difficulty would instantly recur should any international complications arise which required a general arming of our people. The theoretical part of Lieutenant Hawthorne's instruction also includes the nature and effect of the modern tactics, and a consideration of the steps in the development of the art of war which have led to them. It embraces a systematic study of the elements of minor tactics, the ballistics of the infantry weapon, and the influence of topography upon the movements of troops.

The military department has enjoyed a great advantage

through the courtesy of the Commonwealth in allowing the use of the South Armory for our drills. This transfer of the battalion from a small gymnasium to a hall having a length of several hundred feet has enabled our young men to accomplish far more, especially with the increased intervals required by the new tactics, than would otherwise have been possible. Our thanks are due to His Excellency Governor Russell, to Gen. Samuel Dalton, Adjutant and Inspector General of the Commonwealth, and to Colonel Matthews and the officers of the First Massachusetts Regiment.

With a carefully and judiciously administered system of excuses for students physically disqualified, the drill exercises of the first year become an excellent means of physical development and training. The arms in use are no longer the heavy, old-fashioned musket, but the cadet-rifle, as used at West Point. Lieutenant Hawthorne has all that appreciation of the physical development of the soldier which characterizes the modern officer, as compared with the officer of fifty or even twenty years ago. Gymnastics are now a regular part of the technical training of the soldier in every army; and personal "setting up" is quite as carefully looked after as perfection in the movement of the mass. Indeed, it may almost be said that there is no "mass" in modern war, and that the work of the individual is acquiring every year greater and greater importance. Lieutenant Hawthorne is carrying out his work in this spirit; and Mr. Boos, in the gymnasium proper, is cordially co-operating to give every student a chance for straightening himself and bringing out the possibilities of his form. Under such a regimen, I believe that drill at the Institute will have a constantly increasing value in the physical development of the first-year students. It is, however, essential, as was stated, that the system of excuses from military drill should be well conceived and judiciously administered. "One man's meat is another man's poison;" and exercises which are of profit to nineteen students might do harm to the twentieth. In this view the Faculty have appointed a standing committee on excuses

from military drill, to consider carefully every application for excuse, with a view to prevent any shirking on the one hand, and to avoid the danger of physical injury on the other.

The Libraries.

The problem of promoting the utmost use of books of reference, of scientific journals, manuals, and encyclopædias, has long received the attention of the Faculty of the Institute. It is believed that the result here reached represents the highest possible success in this particular. The Institute contains ten regular libraries, in addition to the collection of books in the Margaret Cheney room. Each of these libraries is in immediate connection with the department whose wants it is intended to supply. Each has its own card-catalogue, while a duplicate of every card is found in the office of the general librarian. Five of the libraries have their own special librarians; Mr. Andrews, the librarian in chief, takes personal charge of the chemical library; the remaining four are looked after by the professors of the departments concerned or by their assistants.

Such a disposition of our very valuable collections of course involves a certain amount of duplication, since the same book may be required for frequent use by more than one department. The amount of this duplication, however, is not large, being estimated by Mr. Andrews not to exceed two per cent. This system also involves a certain increase of labor and expense in the administration; but both these disadvantages are many times outweighed by the enormous advantage which comes from having the books subject to immediate consultation by the students. I do not think it would be an exaggeration to say that the use of books by our students is fourfold what it would be if the students were required to go to a large general library and take out the desired volumes with the formalities usual in such cases. With us, books are tools for handy use; just as much so as the apparatus of the chemical or physical laboratories. The

student steps from his desk into a room but a few feet away, looks through the shelves for the volume he requires, consults this for the, perhaps, single, small point concerned, and leaves it on the table to be returned to its place by the librarian in charge. Under such a system the students learn to use books with freedom; and I need not say to the Corporation that this is of itself no inconsiderable part of the education of a scholar.

But I should not do justice to the subject if I did not allude to what is, perhaps, the most striking result of our system, which is the loyalty and integrity of the students in the use of the privileges thus afforded them. Professor Cross has recently told me that during the ten years since his library was set up in the Walker Building, though during all that time until the beginning of the present year there was no one in charge of the shelves or the room, not a single highly valuable book has disappeared, while the losses of books of ordinary value have been so small as to come within the normal limits of accident or thoughtlessness, the aggregate losses of ten years being hardly worth considering. Moreover, during this long term, Professor Cross assures me he has never once had occasion to complain of boisterousness or disorder on the part of students who, in the main entirely unwatched, have used the room occupied as a library and reading-room. Another very noticeable instance of the care and fidelity of our students in the use of books has just come to light through the completion of the catalogue of the Geological Library. This library has, from and including 1889, received several large additions of rare and valuable books, chiefly through the generosity of Mrs. Rogers; but the onerous duties of the librarian have not allowed these collections to be catalogued until the last summer. Upon comparing the card-catalogue with the lists of books received during five years, there has been discovered only the most inconsiderable loss from all sources.

I have before adverted in other reports to the exception-

ally large periodical literature, in the sciences and in technology, received at the Institute. In 1887 a list of periodicals was prepared by the librarian. In connection with our exhibit at Chicago, a second edition of this list was printed. The new edition shows that the Institute is regularly receiving four hundred periodicals, exclusive of annuals or serials, and of official reports. Thirteen copies received are duplicates, leaving the total number of separate periodicals 387. Our list also contains 51 complete, and 42 incomplete sets of periodicals not now received, and also 78 annuals or serials, exclusive of official reports. The total number of separate publications appearing on the list is therefore 558.

The total accessions to the library for the year have been 5,150, of which 2,072 have been received as gifts or in exchange, 2,440 obtained by purchase, and 638 by binding periodicals and pamphlets. The net accessions have been 5,009, of which 3,607 are volumes, and 1,402 pamphlets. The distribution and cost, including binding, of these accessions, and the total number of volumes in each departmental library are shown in the following table: —

Library.	Vols. added.	Pphs. added.	Cost.	Pamphlets (bound and unbound) already catalogued.	Total No. of volumes.
General	474	293	$510.53	2,092	3,093
Engineering	764	435	1,325.35	2,106	4,547
Mining	111	36	216.57	183	1,276
Architectural . . .	71	50	291.81	91	1,202
Chemical	362	144	643.23	1,114	5,423
Biological	164	23	233.75	206	1,423
Physical	541	82	842.30	334	3,845
Political Science . .	861	191	792.73	2,021	6,012
English	154	. .	165.22	31	1,650
Geological	88	145	124.92	287	1,388
Margaret Cheney Room	17	3	. .	11	560
Total	3,607	1,402	$5,146 41	8,476	30,419

The total number of pamphlets in the Institute is not less than twelve thousand.

Four thousand five hundred and seventy-five cards have been added during the year to the main catalogue, which now contains 27,682 cards, covering 30,350 volumes and 8,476 pamphlets. During the summer the Geological and Architectural Libraries have been catalogued. Nineteen hundred and thirty separate orders for books were given, and 182 were returned to the departments, because the books were already in the Institute or had been ordered for it. The saving of unnecessary duplication is shown by the fact that only twenty-six of these orders were repeated. Eight hundred and twenty-one orders for binding were given, covering 1,464 volumes, at a cost of $1,062.88. Besides an increased number of gifts of single books, the Institute has received from the Royal Institute of British Architects seventeen volumes of their Transactions, as far as possible completing our set; from the United States Coast and Geodetic Survey, one hundred and sixty maps; and from Professor Wells of the Institute, a set of his works.

Changes in Buildings and Grounds.

Although the Architectural Building is but a little more than a year old, the school again feels pressure for room at many points. We could to excellent effect use another building for additional recitation-rooms, library and reading-rooms, faculty-rooms, etc. We need not only a large room to be used as a faculty-room exclusively, but also several rooms in which groups of teachers giving instruction in the same lines might have opportunities for conference, for comparing marks, for keeping their records, and for consulting personally with students. We need, also, at least ten additional recitation-rooms for moderate-sized classes, both to avoid inconvenience through conflict of appointments, and to secure better ventilation. We also need one or two more large rooms in which the students may pass the intervals between recitations or lectures, studying their lessons, reading up their notes, etc.

But while our buildings have not been increased, the grounds of the Institute have been very greatly extended, if not in actual area, at least in the value which the new land represents. We should have been glad if the issue, whether certain parcels adjoining the Engineering and Architectural Buildings should be purchased by us or be allowed to become the property of others, could have been postponed for a few years, when peradventure our funds might have become more ample; but, unfortunately, this issue could not be postponed. During the past year it became evident that the Institute of Technology must either buy the skating-rink property, on Clarendon St., and the Jordan land lying between our property on Trinity Place and the Providence Railroad, or else be prepared to see both these pieces of real estate hopelessly lost. Such an issue having been fairly made, it became impossible that the government of the Institute should take more than one view of the question. It was not to be thought of that this great and growing school should be left without a square foot of land upon which it could build in future. It was in such a situation, and with such a sentiment, that the tracts in question, aggregating 50,000 square feet, were purchased, at a cost of about $277,000.

To an institution already so heavily loaded with burdens, almost beyond its strength to bear, the accession of such a body of indebtedness constitutes a painful and almost dangerous strain; yet the Institute of Technology ten years ago took up an even larger burden of debt, though then with a far smaller number of students, fewer graduates, and a much narrower sphere of influence and reputation. Nor has the treasury been left to bear this year's new burden altogether unrelieved. Two considerable sums have come to us by bequests from well-proved friends of the school, which, in their aggregate amount, when fully paid over, will provide a part of the cost of the new land. Had it been possible for us to avail ourselves of these benefactions for current expenses, our financial condition would have been greatly

improved. As it is, the school is poorer than ever before in its history, if we compare current receipts with necessary current expenditures.

Summer Schools.

The summer school in Topography, Geodesy, and Geology was held during the month of June near Keeseville, N. Y., in the northern part of the Adirondack region. This location was specially favorable for almost all branches of the work undertaken, and the school was in every respect the most successful that has been held. Twenty-two students were in attendance, — twenty being from the junior class, or more than one half the total number of students in the class in this course. The work was under the supervision of Professors Burton, Porter, and Niles, assisted by Mr. Robbins, and by Mr. G. A. Campbell of the class of 1891.

The topographical work consisted of a plane-table survey of about two square miles, including a complete hydrographic survey of Auger Lake. The contours were put in at vertical intervals of ten feet. The bottom of the lake was contoured at six feet intervals from the soundings. The geodetic work consisted in the measurement of a base-line one kilometer long, with triangulation to known coast-survey stations, by means of which latitude, longitude, and the elevations in the area surveyed were very accurately determined. The measurement of the base-line was made with the steel tape, with a probable error, in three measurements, of one part in 1,700,000. In this work the temperature of the tape was determined by a method never before successfully used; namely, by measurements of its electrical resistance. This part of the work was under the direction of Mr. Campbell, who devised a light and portable apparatus for measuring the resistance in the field. The hydraulic work consisted in measuring by various methods the discharge of the Au Sable River. Weir measurements of the discharge of Auger Lake were also made, as well as measurements in mill flumes.

Moreover, the lake afforded opportunity for rating the current meters. The work, therefore, was of an extremely varied character. The geological work consisted in making a geological profile, two miles long, and in studying the geology of the neighboring region, the field instruction being supplemented by lectures in the evening.

The Summer School of Metallurgy, last June, was arranged in connection with the World's Fair. The various metallurgical works in Chicago and the Exposition were visited on alternate days. The School is particularly indebted to the following gentlemen: —

A. Eilers and F. B. F. Rhodes, of the National Smelting & Refining Co. of Chicago;

R. Forsyth, E. A. S. Clark, and Jasper Whiting, of the Illinois Steel Co.;

Otis T. Stantial, of the Illinois Malleable Iron Co.;

E. F. Eurich and R. H. Colby, of the Chicago and Aurora Smelting & Refining Co.;

H. L. Bridgman, of the Chicago Copper Refining Co.;

John L. Shortall, Frank Wells, Solomon Sturges, and F. W. Clark, of the Northwestern Association.

Courses I. and XI. Civil and Sanitary Engineering. — The permanent staff of instruction in the Civil Engineering Department of the Institute is the same as last year, except that Mr. A. G. Robbins, for several years Instructor in Civil Engineering, has been appointed Instructor in Highway Engineering, in place of Mr. F. E. Foss, who has been called to the chair of Civil Engineering in the State College of Pennsylvania.

No important changes have been made in the course of study during the year; but increased attention is being given to certain branches. A room has been engaged on Myrtle Street (Beacon Hill) especially for geodetic work, consisting of magnetic and astronomical observations, pendulum observations, etc. This location, besides being on natural ground, is but slightly affected by electric currents. A great need, in this branch of instruction, is a separate building in some

suitable locality, devoted to geodetic observations, which would enable the department to increase still further the efficiency of the instruction in this branch.

Special lectures in the department of Civil Engineering were given during the past year by Mr. Eliot Holbrook, on Railway Maintenance; by Mr. J. R. Freeman, on the Hydraulics of Fire Protection; by Col. C. W. Folsom, on Sewer Construction; and by Mr. Desmond Fitzgerald, on the Boston Water Works. The lectures on Railway Signals, by Mr. Blodgett, were given as usual.

A new edition of Professor Swain's Notes on the Theory of Structures was issued last year. Professor Allen has also published his Tables for Earthwork Computation. The equipment of the department has been materially increased during the past year. The larger number of students in Surveying has rendered necessary the acquisition of two new plain transits, a light mountain transit for reconnoissance work, one of Buff and Berger's precise levels of a new pattern, and a German instrument, known as the "tachy-graphometer," which is used in connection with the plane-table, for plotting stadia measurements directly. Various smaller instruments have also been added, including a sextant, a pantagraph, and the electrical apparatus elsewhere referred to for use in steel tape measurements.

The apparatus in the Hydraulic Laboratory has been increased by a Venturimeter, a new set of gates for the large tank, a Crosby gauge-tester, and various smaller pieces of apparatus and fittings. The most important addition, however, and one which was much needed, is a large Blake duplex steam-pump. A Davis plunger power-pump was loaned to the laboratory last spring, so that nearly all the different kinds of pumps are now represented. A current meter, of a recent type (the Ritchie-Haskell), has also been added to the equipment for field hydraulic work. The number of students in this branch of instruction has steadily increased, and further equipment will be needed the present year.

Col. James Francis, of Lowell, has presented to the Institute a large number of beautifully made brass orifices and other apparatus used by the late James B. Francis and the late Uriah Boyden, in experiments made many years ago. Mr. John R. Freeman has loaned a delicate Pitot-tube apparatus for measuring the distribution of velocity in pipes. The Tuerk Hydraulic Power Co. have loaned the school one of their motors for use in the laboratory. Acknowledgment is due in this place to Col. James Francis, for allowing the students to make use of the flumes at Lowell for hydraulic measurements; to President Bliss and General Manager Barnes, of the Boston and Albany R. R., and to General Manager J. W. Sanborn, of the Boston and Maine R. R., for courtesies extended to students; also to Mr. McClure, the city engineer of Worcester, and Mr. Page, of Concord, for assistance in connection with excursions made to works under their charge.

It may not be out of place here to refer to some statistics recently collected with reference to summer work done by students in Civil Engineering. The question is frequently asked, To what extent are students able to obtain work during the summer, and in this way help work their way through the school? Notwithstanding the business depression during the present year, it has been found that, of twenty-nine students in the fourth year in Civil and Sanitary Engineering, twenty-one, or 72.5%, were at work during the greater part of the summer; while of thirty-four students in the third year, twenty-one, or 62%, were so employed. All but two of the forty-two were engaged in engineering work. The earnings of the fourth-year men averaged $54.50 per month; while those of the third-year men averaged $51.00. Of those who did not work during the vacation, many preferred to rest.

The library is well equipped with books and periodicals relating to highways, and new publications are procured as soon as issued. The department is also provided with apparatus for making tests of the physical qualities of road-materials, such as specific gravity, porosity, wearing qualities, etc. It also possesses a collection of samples of materials

used in road construction; and a special room has recently been set apart as a road museum. The development of the course described above, the engagement of a special instructor and of lecturers in Highway Engineering, and the enlargement of the library, are mainly due to the contribution of Col. Albert A. Pope, who has furnished funds to meet the increased expenses involved.

No material changes have been made in the plan of instruction in Course XI., and no special remarks are called for here. There are at present several students in this course in each of the three upper years.

Highway Engineering. — In view of the increased interest which the subject of Highways is attracting throughout the country, attention may here be called somewhat in detail to the work of the department in this direction. The instruction in Highway Engineering comprises a detailed consideration of the location, construction, and maintenance of roads, as well as of city streets and pavements. This instruction is given in several courses, only one of which bears the name of Highway Engineering. In the course in Railroad Engineering, the alignment and location of common roads, including questions of grades and curves, are considered at great length, and a large amount of time is given to the computation and measurement of earthwork, and the staking out of work in the field. The structures which occur on highways, such as bridges, retaining walls, etc., are studied in the course on the Theory of Structures.

Leaving the study of structures out of account, it may be said that the greater part of the work of the third year which is classed as Railroad and Highway Engineering has a direct and immediate application to the subject of highway construction. This work extends throughout the year, and consists of seventy-five lectures, together with a large amount of work in the field and drawing-room. In the second term, a special course is given (included in the above), on Highway Engineering in its restricted sense, involving a study of those matters pertaining specifically to roads; that is to say, it includes a study

of the methods of constructing and maintaining the road foundation and surface, of the materials used in road construction, of city streets and pavements, and of specifications for road and street work. The special course is given by the Instructor in Highway Engineering, while the remainder of the course is given by the Professor of Railroad Engineering. In addition to these, lectures are given each year by prominent highway engineers. During the past year two lectures were given on road construction by Mr. E. P. North, of New York, and two by Mr. James Owen, of Newark, N. J., both gentlemen having a national reputation in their specialty. The attention of students is also directed to streets and roads under construction, and excursions are made to points of special interest. The work of the fourth year is optional, except so far as the drainage and cleansing of streets and roads are studied in the course in Sanitary Engineering. Students who desire have the opportunity to direct their fourth-year work in design, as well as their thesis-work, toward the subject of highways.

Course II. Mechanical Engineering. — The Emery testing-machine, of three hundred thousand pounds capacity, obtained through the bequest of the late T. O. H. P. Burnham of Boston, arrived about the middle of the last school year, and has already proved itself of great value. It has been in use ever since it was set up, both in giving instruction to the students and in making investigations; and although its late arrival, and the unavoidable delays which always accompany the erection and adjustment of so large a machine, have not left a great deal of time for investigations, nevertheless, a considerable amount of work has already been accomplished by way of determining the compressive strength, per square-inch, of timber across the grain, under different proportions of thickness, and of compressed surface, using both spruce and yellow pine. The machine is capable of testing, in compression, a specimen eighteen feet long, or one twelve feet long in tension. The two large screws which resist all the load that is put upon the specimen are each seven inches in diameter

at the outside of the thread, and the whole construction is one of great solidity. The travel of the piston is forty-two inches. Although the Burnham Machine weighs seventy-nine thousand pounds, it is amply supported by the floor of the laboratory. The Laboratory of Applied Mechanics is to be congratulated on the possession of this machine, not only because it has so great a capacity, but also because of its extreme delicacy. A crane, with two travellers, has been erected over the machine, with a capacity of two tons, by means of which the specimens, the tension-holders, the compression-platforms, and other heavy pieces can be handled. In addition, a set of tension-grips has been made for the machine, and also some measuring apparatus.

The work of the laboratory upon transverse strength, having outgrown the capacity of the machine for testing beams, of fifty thousand pounds capacity, erected in 1881, a new machine has during the year been substituted, which has a capacity of one hundred thousand pounds, and can test a beam up to twenty-six feet span. Not only is the capacity of this new machine double that of the former, but it is much superior in workmanship and in general adaptability for its purpose. It will enable the department to carry on all the work of investigation in transverse strength which is at present in contemplation. The four jackscrews of the machine are provided with ball-bearings.

For testing beams up to fourteen feet span, a machine of eighteen thousand pounds capacity has been added, thus leaving the large machine free for the heavier work. Another important addition is a machine for making torsional tests. It is capable of testing, in torsion, a shaft three inches in diameter, and of a length limited only by the distance between the walls of the room in which it is placed. It was designed by Prof. E. F. Miller, and is capable of performing a much better piece of work than the ordinary torsion-machines in the market. All the apparatus mentioned has been added to the Laboratory of Applied Mechanics. To the other portions of the Engineering Laboratories have been added the following apparatus: —

1st. The large duplex steam-pump, for the joint use of the Steam and the Hydraulic Laboratory, which I have before referred to in speaking of Course I.

2d. An indicator-tester; that is, apparatus for determining the corrections of steam-engine indicators under steam pressure by direct comparison with mercury columns, the indicator being under conditions similar to those of practice. This enables us to do far more accurate work in this line than has ever before been done.

3d. A machine for determining the coefficient of friction f lubricating oils.

4th. A portable orifice tank for measuring moderate quanties of water, when it is not convenient to weigh them.

5th. A machine for testing the transmission of power by opes.

6th. A plunger-pump, loaned to the laboratory.

7th. A three-inch brass water-meter, presented by the Vorthington Pump Company.

8th. An ejector, presented by the Hancock Inspirator Company.

It will thus be seen that the laboratory is constantly developing in equipment and in the work which it accomplishes.

A number of investigations were, as usual, carried on in connection with the thesis work of the students, and some of hese will be published. A new and enlarged edition of the notes on the "Action of the Reciprocating Parts of the Steam-Engine," by Professor Lanza, has been printed, containing considerable new material. A paper on the "Measurement of Steam by the Flow through an Orifice" has been presented o the Society of Arts by Professor Miller and Mr. Read.

Course III. Mining Engineering and Metallurgy. — The work of the Mining Department is steadily advancing. It is the opinion of Professor Richards that each year the classes in blow-pipe, in mining engineering, in metallurgy, in assaying and metallurgical laboratory work are a little better taught than the previous classes. The appropriation made to the department is, after the necessary repairs and running ex-

penses are paid, put into permanent and substantial improvements in apparatus, and into standard books and periodicals. The mining and metallurgical summer schools are each year better managed and more highly appreciated by the students. That the present depression in mining business does not deter men from taking the mining course is shown by the numbers included in the second, third, and fourth year classes, which are respectively eighteen, sixteen, and six, — a larger total number than ever before. A new series of lantern-slides have been obtained for illustrating Professor Hofman's lectures on the Metallurgy of Lead and Silver. A new balance has been purchased for the assaying class. The concentrating plant has been improved by the readjustment of the slime-table, which now does a very high grade of work.

Professor Richards is engaged in an ore-dressing investigation which bids fair to explain certain parts of the jigging operation which have never been understood, and which have, therefore, never been applied with the intelligence they deserved. The apparatus is novel, and the results so far obtained are very interesting. The plant for the study of the fusibilities of fire-clays has come into existence within a year, and is now about to receive a new Deville furnace for extremely high heats. The zeal and care bestowed by Mr. Lodge are making the mining laboratory work more effective than ever before. The edition of lithographic notes on Metallurgy of Iron has been exhausted; and these notes will this year be revised and brought up to date.

Professor Richards found no simple and effective stadia for his summer-school work in geological surveying. He has accordingly designed and perfected a new instrument for the use of the students. This instrument does so much more accurate work than those previously designed that its usefulness will probably not be confined to the school. The surveying equipment has also been strengthened by the addition of two alidades. The library is steadily growing, the plan followed being to purchase only standard works and to complete the various sets of periodicals in which all the latest and best pro-

fessional information and experience is to be found. This year the files of "Thonindustrie Zeitung" and "Stahl und Eisen" have been completed, and two new annuals have been added; namely, Freiberger Jahrbuch and Kärnthner Jahrbuch. The subject-catalogue, the preparation of which is in Professor Hofman's hands, is proving more valuable than ever, as is shown by the high class of professional memoirs prepared by the mining students.

The walls of the laboratory have received tablets, —

THE JOHN CUMMINGS
LABORATORY OF
MINING ENGINEERING AND
METALLURGY.

which tell the students of the invaluable services Mr. Cummings has rendered to the school.

Course IV. Architecture. — The Department of Architecture opened the year with the largest number of students in its history, notwithstanding the recent marked increase in the requirements for special students. Among the new students here are not less than twenty-three college graduates. Seven of the students in Architecture are taking a purely graduate course. Professor Despradelle has begun his work at the Institute under the most flattering auspices. The students have met him with enthusiasm; and his lectures and individual instruction in the drawing-room have given an inspiration to the work of the department which it has never before enjoyed in equal measure. Professor Chandler is thoroughly in earnest in trying not only to maintain unimpaired the traditional standard in this department, but to build up a class of students who, having completed all the undergraduate work, can give at least an

entire additional year to design. The library of the department and its collections of photographs have been largely increased during the year, both by gifts and by purchase. A large and admirable series of lantern-slides, two hundred and fifty in number, for illustrating the lectures in Renaissance Architecture, has been made by Mr. Lawrence. The instruction given in water-color, by Mr. Ross Turner; in the history of ornament, by Mr. Howard Walker; in pen and ink, by Mr. Gregg; in modelling, by Mr. T. H. Bartlett, — is of the highest order. Mr. Adams has been very successful during the past year in his conduct of the life-class. The changes of the year in the course schedule, giving more time to professional work, has allowed the course in Architectural History to be extended.

The Architectural Building, which seemed so large a year ago, is now completely filled, almost every desk which can be put into the drawing-rooms being occupied. The main drawing-room at the top of the building, where instruction is given in water-color, free-hand drawing, sketching, life-class, etc., has proved wonderfully useful. Its arrangements for the control of the light are unique. During the year the room has been crossed in several directions by rods, over which curtains with rings can be drawn at pleasure, dividing the room into a considerable number of smaller drawing-rooms. Notes on Shades and Shadows have been prepared by Mr. Lawrence, and printed for the use of the classes. By the generosity of many manufacturers the Museum of Building Appliances has been very greatly enriched. From the executors of the will of the late George Snell, Esq., the Institute has received his sketches in four large volumes, and also a collection of Gothic casts, originally given to Mr. Snell by Sir Charles Barry.

Courses V. and X. Chemistry and Chemical Engineering. — I have already referred to the great loss sustained by the Chemical Department in the death of Professor Norton, and, in a general way, to the provisional arrangements made for carrying on the work of instruction relinquished by him. It

is appropriate at this point to name the special lecturers who have consented to assist us in this emergency, together with the subjects they have severally taken for discussion before our classes. These are, — Mr. Frank G. Stantial, S. B., on mineral acids and ammonia; Mr. Arthur D. Little, on paper; Mr. George R. Underwood, S. B., on glue; Mr. Charles W. Hinman, S. B., on illuminating gas; Mr. Walter S. Allen, S. B., on fertilizers; Mr. Charles D. Jenkins, S. B., on pottery and tiles; Mr. Webster Norris, S. B., on rubber; Mr. C. S. Doggett, on acetic acid and pigments; Mr. Louis J. Schiller, on sugar and sugar refining.

Nearly all these gentlemen received their training at the Institute, and are actively engaged as superintendents or chemists in leading works. In addition to these lecturers on special topics, Mr. Henry J. Williams, formerly assistant of Professor Norton, and later of Professor Potter of Washington University, St. Louis, and of large independent experience in many lines of chemical industry, is giving an extended course of lectures in various branches of Industrial Chemistry. Dr. Thorp, whom I have already named as a regularly appointed instructor in Industrial Chemistry, graduated from the Institute in 1889, and was for the two years following assistant in Industrial Chemistry with us. He has since obtained his doctorate at the University of Heidelberg, and has for some months been engaged in studying Industrial Chemistry, and particularly the art of dyeing, in the Yorkshire district of England. He will enter on his duties at the beginning of the second term.

To the great gratification of the Faculty of the Institute, Professor Crafts has consented to take charge of the instruction in Organic Chemistry. The accession of a chemist of Professor Crafts's reputation, a teacher of his experience and exceptional powers of inspiring interest and enthusiasm on the part of the students, marks an era in the history of the Institute. If only the means at our disposal were sufficient to provide him further facilities and opportunities and to give full scope to his powers, we might well feel that our

Chemical Department was far on its way to the highest success. The increasing demand for young chemists throughout the country is producing its legitimate effect in the larger number of students entering our course in Chemistry.

Courses VI. and VIII. Electrical Engineering and Physics. — During the past year the work in the class-rooms and laboratories has been steadily improving in its various details, and has been carried on with increased efficiency. I know of nothing which would give a more striking view of the results of steady, progressive growth in building up a great department of instruction, and of the hopelessness of attempting to extemporize a technical school, no matter with what wealth of resources and endowments, than would a careful study of the development of the courses under Professor Cross's administration. There has not been a year since my accession to the Presidency in which the Department of Physics has not made a distinct and marked advance; not a year in which the instruction has not been appreciably better than that in the year preceding. Much, doubtless, of what has been thus attained here might be imitated and repeated elsewhere under judicious management; but much of it also has arisen from the continually nicer adaptation of means to ends, the continually widening horizon of teachers, and the progressively better preparation of the students for their work.

Large accessions of apparatus have been made during the year, especially of heat and electrical measuring instruments. The new special laboratories of acoustics and optics have proved of great value. In only one particular has the department suffered; namely, through the crowding of its lecture and recitation rooms, due partly to the large increase of the second-year class, and partly to the introduction of additional class exercises. During the year the usual number of original papers have been published from the Rogers Laboratory; and there is still a large amount of material suitable for publication which is only waiting for some of the instructors to find time to put it into proper

form. Toward the close of the year, a circular was issued, descriptive of the courses in Electrical Engineering and Physics, and illustrated by pictures of laboratories and apparatus.

The instruction in Course VIII. has been much enlarged by the introduction of new courses in mathematics. Through a judicious condensation in the earlier years, the Department of Physics is now able to present in the fourth year an extended course on Fourier's Series and La Place's Coefficients,—branches of mathematics essential to any complete course in physics, but which in most institutions are offered only to graduate students, or are not given at all.

Another change in the course of instruction, which is of even greater importance because affecting a vastly greater number of students, has been effected by the introduction of recitations, supplementing the physics lectures of the second year. Two hours a week are given to these by each student, the class of about three hundred and twenty-five being divided for this purpose into ten sections. These recitations, which are conducted by Mr. Wendell, have already proved of great benefit to all grades of students, although they were introduced rather with reference to the weaker than to the stronger men. Not only do these "quizzes" result in more thoroughly grounding the whole body of students in the fundamental principles of the subject, but they also serve as a means of communication and better understanding between the instructing staff and the individual pupils. The instruction given by Mr. Derr to students of the Boston Normal School of Gymnastics will be mentioned elsewhere.

At present the Department of Physics is specially striving to secure a greater concentration of the preliminary and general work of Course VI. in the first three years, in order that there may be room for greater specialization in the fourth year. Of necessity, in a field so wide as electrical engineering, and with the large amount of training in theory and in exact measurement which is imperative, progress cannot be made rapidly. But each year sees a distinct advance

in this direction. One important special course introduced during the last year should be particularly mentioned, — that, namely, on the design of Dynamo Machinery, by Mr. H. F. Parshall, of the General Electric Company. Mr. Parshall designed the great dynamos furnishing the current for the Intramural Railway at the World's Fair in Chicago, and is highly competent to give the instruction referred to. It is expected that other courses of a like advanced character will be given shortly.

Course VII. Biology. — Somewhat, I confess, to the disappointment of my expectations, Course VII. as a course in preparation for medical studies has not grown in popularity. Whether due to the refusal on the part of the medical schools to give adequate recognition to the extremely valuable training in such a course, or to other causes, it remains true that this effort of the Institute of Technology to increase its usefulness to the community has not met with considerable success. On the other hand, the activity of the Biological Department is now greater than ever in the training of bacteriologists; in giving to our young chemists and sanitary engineers much-needed instruction bearing upon their professional studies; in promoting investigations regarding water-supply and the disposal of sewage; and lastly in training teachers of natural science for our secondary and higher schools. The number of the last-named class engaged in the biological laboratories of the Institute is already large, and promises to increase. Moreover, the industrial relations of biology are every year becoming more extended and intimate. The practical importance of the micro-organisms involved in fermentation, putrefaction, and decay; in the waste of food and the destruction of timber; in the purification of sewage and water; in the conversion of manures and in nitrification; in brewing, vinegar-making, and the like, — is fast coming to be recognized as justifying and requiring the most thorough and careful investigation of this subject, so that to-day no study can be more properly called technical than Bacteriology. Our laboratory is admirably organized

and equipped for the pursuit of this branch of research; and under Professor Sedgwick's inspiring leadership, work of the highest value is constantly in progress. The instructing staff has been materially strengthened by the appointment of Dr. Robert P. Bigelow and Dr. Theodore Hough, in Zoölogy and Physiology respectively. These gentlemen have come to us from the Johns Hopkins University, and have already shown excellent quality as teachers. Professor Sedgwick retains his connection with the State Board of Health; and a part of the biological work of the Board is carried on at the Institute. In investigating still further the sanitary aspects of public water-supplies and milk-supplies, Professor Sedgwick has made extended inquiries of much sanitary importance in different cities and towns of the Commonwealth, the results of which will be found embodied in a series of papers lately published by the State Board. The recent introduction of an option in Bacteriology into the last year of the course in Chemistry affords a gratifying recognition of the practical value of the biological work of the Institute.

Course IX. Department of General Studies. — Notwithstanding the severe losses which Course IX. has sustained through the resignation of Professors Carpenter and Levermore, the number of students taking this course is more than maintained; and the character of the work has, it is believed, suffered no impairment. The addition to the teaching staff of Dr. William Z. Ripley has greatly increased the efficiency of the work in Economics and Sociology. Dr. Ripley is the first teacher, in this department, of our own breeding; and I cannot doubt that his intimate knowledge of the history, character, and the present needs of the Institute will be a real addition to his other qualifications as an instructor here. I have already spoken of the special courses of lectures given this year by Professor Jameson and Messrs. Fiske and Lowell.

Course XII. Geology. — During the year instruction has been given in all the studies of the department, and Professor Niles has assisted in the work of the Summer School of Topography and Geodesy.

A party of five, under the leadership of Professor Crosby, spent the first two weeks of June in New York, at localities rich in fossils; and two members of the party continued the work two weeks longer. This gave an excellent opportunity for observations in a region quite different from that in which the Institute is located. The expedition was especially successful in obtaining specimens. A large proportion of these are of species not before fully represented in our collections. The material will be of special service in laboratory work in palæontology.

To the equipment of the department there has been added a machine for slicing, grinding, and polishing sections of rocks, fossils, and other specimens, with independent motor-power. A new and much-needed case has been provided for the increasing collections in Structural Geology. Some very desirable additions have been made by purchase and otherwise to the mineralogical and petrological collections, including a large basalt column from the Rhine district. The collections in Economic Geology have been enriched by a series of polished marbles given by Mr. J. W. Tufts, of Boston, by extensive series of whet-stones and oil-stones contributed by the Pike Manufacturing Company, by ores received in exchange from the Geological Survey of Missouri, and various minor additions. A valuable collection of fossils and fossiliferous rocks, numbering eight hundred and seventy-five, has been received from Professor Niles of the Institute. The specimens have been identified, labelled, and arranged in the collections of the Department. The equipment for work in micro-lithology has been increased by the addition of a new microscope and suitable accessories. Mr. Nichols has classified the numerous maps, charts, and diagrams of the department and arranged them systematically in cases.

Course XIII. Naval Architecture. — The work in Naval Architecture detailed in the Report of last year had reached such a stage that it appeared practicable to establish it as an independent four-year course; and it was believed that such action would promote the further growth of this

branch of instruction. As now arranged, the course in Naval Architecture has a continuous series of lectures under that title twice a week throughout the third and fourth years, thus making it possible to give an adequate treatment of the subject.

The subjects which now receive further attention than was formerly possible are: Rolling of ships in an unresisting medium, in water and among waves; the trochoidal theory of waves, and the theory of waves of translation; waves made by ships and the effect of such waves on the propulsion of ships; resistance of ships due to friction, wave-making, eddy-making, and to the effect of the wind on hull and rigging; experiments on the resistance of ships by towing and otherwise; experiments on models of ships in a tank, results obtained by W. Froude and R. E. Froude; effect of the propeller on the resistance of a ship; propulsion of ships by steam or sails; sail-plans, centre of effort and centre of lateral resistance of a sailing-ship; steering and manœuvring a ship under steam and under sail; methods of procedure for laying out the preliminary design of a ship for a given purpose; methods of carrying out and completing a design.

Accompanying the course of lectures, the students have two or three exercises a week in the drawing-room, in which they make the drawings and calculations necessary for the determination of the displacement, stability, and strength of a ship; also the design of the lines of a ship for a given service, and the preparation of the plans of the decks and midship section and the specifications for the scantlings.

In laying out the course in Naval Architecture, the importance of general construction-engineering, as taught in the course in Mechanical Engineering, was kept in mind; and none of the essentials have been sacrificed. The changes from Course II. are, in brief, — the omission of machine design and hydraulic motors from the fourth year, and the mechanism of cotton machinery from the second year. The time for mechanical engineering drawing has been transferred to naval architectural drawing, and considerable additional time

has been given. The woodwork in the shop has been omitted, and the forging transferred from the third to the second year.

The following material for work in Marine Engineering and Naval Architecture has been received this year: —

(*a*) Drawings of the lines and framing of the U. S. cruiser "Cincinnati," which, with the drawings of the machinery already in the department, make a complete set of great value.

(*b*) Complete drawings of the S.S. "Gloucester," recently built by the Maryland Steel Co.

(*c*) Complete drawings of the engines of the U. S. gunboat "Castine," built at the Bath Iron Works.

(*d*) Plans and specifications of lighthouse tenders, lightships, and revenue steamers, from the Treasury Department.

A nearly complete set of the Transactions of the Association of Naval Architects and many other valuable books have been added to the library. Three additional Amsler-Laeffel integrators have been purchased, making five now belonging to the department. It would be of great advantage to have a separate drawing-room assigned to the department, in which students could be provided with tables at least twice the size now available, so that drawings might be made as large as is customary in the draughting-rooms of ship-yards.

The Residence of Students during Term-Time.

For ten years the President has, in his Annual Report, presented to the Corporation statistics of the home-residence of students, showing the distribution of the total body among the several States of the Union and various foreign countries from which they come to us. In the preparation for the present Report, it has seemed to me that matter both interesting and instructive could be obtained by collating facts regarding the residence of our students while in attendance upon the school; and this has now been done for the first time. The object has been to throw the students into classes

according to the distance which they have daily to travel, coming to and going from the school, and also according to the means of locomotion employed. The figures obtained are not exact, because there are certain cases of districts which have more than one mode of communication with the Institute. The object of the inquiry is to give a general view of the situation as regards the time and strength consumed. For this purpose the students have been divided into five classes. The first class comprises those who reside in Boston proper, and who may easily walk to and from the school, or come and go by short street-car trips. If these students habitually walk, the time occupied is well spent in the exercise obtained. If they ride, the time occupied is comparatively small. The number of these students is 621, or about 54% of the total number. The second class comprises those who reside in suburban Boston or in Brookline or Cambridge, — places reached generally by electric cars, in trips of from twenty to forty minutes. The number of these students is 215. The third class consists of those who reside in towns which as a rule are reached from Boston by railroad only, but which are not more than ten miles from the city, according to the tables of railroad distances. This group of towns comprises, besides many others, Quincy, Hyde Park, Braintree, Newton, Watertown, Dedham, Woburn, and Lynn. The number of students in this group is 181. The fourth group comprises those who reside in towns more than ten, but less than twenty miles from Boston according to the table of railroad distances; among these towns are Hingham and Sharon on the south, Natick on the west, Concord and Billerica on the northwest, and Salem on the northeast. This class comprises 56 students. The fifth class comprises those who reside in towns more than twenty miles from Boston, — towns only to be reached by rail, and that by considerable journeys, in most cases a walk of twenty or twenty-five minutes from the station to the Institute being added. The number of students in this class is 84. To most of these, residence at such a distance means the loss of from

two to three hours a day, the time consumed in some cases rising to four hours. From the city of Newburyport, thirty-eight miles distant from Boston, eleven students regularly attend the Institute; while students also come and go daily who reside in Rhode Island, at a distance of more than forty miles. Nearly fifty towns send students daily to the Institute. Thirty-one students travel over sixty miles a day for the sake of an education. Newburyport's contingent alone travels over 5,000 miles weekly for this purpose. The daily migration of the whole institution is estimated by Dr. Ripley at upwards of 8,700 miles. In the transportation of our students from their homes to school and in return daily, the Boston and Albany Railroad performs the largest service; the Boston and Maine, and the Old Colony come next in order.

The Lunch-Room.

In connection with the foregoing statistics of the residence of our students during term-time, and the distances they have to travel, it seems appropriate to refer to the lunch-room, which has for the last four years been one of the "institutions" of the school. Strongly as the need of such accommodations for students coming from a distance was from the beginning felt, it was not until the Engineering Laboratories were removed from the basement of the Rogers Building, in 1889, that space could be found for this purpose, and even then it was only obtained by a sacrifice painfully felt by the Mining Department. A room extending from the front of Rogers Building along its left side seventy-six feet, toward Newbury Street, was neatly finished and fitted up with the best modern appliances; and in the fall of that year the lunch-room was opened, at first under the direction of the Women's Educational and Industrial Union. Everything that occurred during the first year tended to show that this new feature was a great boon to numerous students of the Institute; but it was not until the following year, when the scientific direction of the work was assumed by Mrs. Richards,

and the practical direction and business management were placed in the hands of Mrs. Ellen A. King, that the success of the lunch-room was complete. At the present time between three and four hundred students take their midday meal here, the average expenditure being about twenty cents. All cooking is done at the rooms of the New England Kitchen, on Pleasant Street. The materials obtained for the purpose are the choicest, not inferior to those used in fashionable restaurants. Whatever excess of receipts over expenses there may be, after paying the salaries of those concerned, is placed at the disposal of the scholarship committee, for the abatement of the tuition fees of needy and deserving students. The Faculty have the highest satisfaction in the success of the lunch-room, as they know how much difference it makes to the present and future health of the student whether he eats a cold lunch in the corner of a laboratory, or takes something warm and palatable, under pleasant surroundings and in company with his fellows. Even those students who bring their own lunches, wholly or in part, are as welcome as those who resort to the lunch-room for the entire meal.

The Gymnasium.

Pursuing still the subjects which specially concern the health of our students, I would say that the gymnasium of the Institute has been used more than ever before for athletic exercises. The appointment of a scientifically trained gymnast, as director, has awakened considerable interest in physical culture. Volunteer classes are formed every afternoon between four and six o'clock, for systematic exercise, under the direction of Mr. Boos; and a considerable number of students have availed themselves of the advantages thus offered. While the gymnasium of the Institute is by no means designed for the training of athletes for competitive sports, and has little adaptation for such a purpose, it is still very useful for simple, manly exercise, having a clear floor space of 150 by 50 feet, with an abundance of lockers and ample facilities for bathing.

The Chicago Exhibit.

Space having been assigned to us in the Liberal Arts Department of the Columbian Exposition, without any urgency on our part, it seemed the duty of the Institute to make an adequate exhibit of the methods and results of its instruction. This was accordingly done at an expense which has been painfully felt during the past year, but which, it is hoped, will bear good fruit in the future. The space assigned us consisted of 1,080 feet, in two courts upon opposite sides of a broad aisle. These courts were handsomely enclosed and neatly and appropriately fitted up with furniture, cases, desks, etc., for the best presentation of what the Institute had to show. The "installation" of our exhibit was universally regarded as artistic and effective.

The exhibit consisted, in a general way, of the following classes of objects: First, enlarged photographs of buildings, interiors of laboratories, machinery and apparatus, oftentimes with the students at work. Second, architectural and engineering drawings, comprising both ordinary and thesis work of the students, blue-prints, etc. Third, certain statistical tables and graphic charts, showing the distribution of students geographically and by classes; also the residence of graduates. Fourth, charts presenting the studies in each of the principal courses leading to the degree of the Institute. Fifth, a collection of chemical products, the work of the students in Course V., also a series of dyed yarns from the Department of Industrial Chemistry. Sixth, a full set of regular shopwork pieces, in iron and wood, required of all students, as well as numerous examples of special pieces made by students taking more than the time ordinarily allotted. All the foregoing objects and classes of objects were seen by the great majority of visitors to the courts of the Institute, and were doubtless all which the time at their command or their interest in the subject would have allowed them to examine; but beyond these were certain things which, to the careful student of education, constituted the chief merit

of our exhibit. These were, — (*a*) A full set of theses of the graduating class of 1892, 132 in number. Here one who had never visited Boston could for himself see the exact result of four years of training at the Institute of Technology. Here was the work of every member of a large class, shown without editing or correcting by the professor, affording an ample and perfectly just measure of the student's capacity for dealing with a scientific problem and undertaking an original investigation. A more complete disclosure of the weakness or the strength of the Institute could not have been offered to the numerous persons who came to its courts for the purpose of studying critically its methods and results. (*b*) Two-score or more of portfolios and albums, exhibiting by type-written letter-press, by photographs, by mounted specimens of students' work, by statistical tables, etc., the actual kind and order of work, year by year, in the different departments of instruction and investigation. These albums have now been returned to us from Chicago, and will constitute a valuable record of what the Institute was in 1893. (*c*) A manuscript volume containing the professional record and present occupation and address (if living) of twelve hundred graduates and former students of the Institute. The compilation of this volume, requiring a vast amount of labor and care, was conducted by Dr. Tyler; and the result constitutes an important addition to the history of the Institute. The list of present occupations and addresses of graduates published in the annual catalogue has always attracted attention, and has served largely to increase the reputation of the Institute; but the work here referred to not only embraces many former students who did not stay long enough to receive diplomas, but gives for each of these, as well as for each of the graduates of the school, the statement, year by year, of the successive positions held by him and the professional or other work in which he has been engaged. (*d*) A full set of the printed or engraved notes or books, specially prepared for the use of students of the Institute, the whole aggregating several

thousands of pages, with multitudinous plates and illustrations, and constituting a collection which it is believed cannot be paralleled within the range of academic literature.

The formation of the Institute Exhibit was provided for and carried on by a Committee of the Faculty, of which Professor Richards was chairman. Mr. J. H. Stanwood, of the Civil Engineering Department, acted as the executive officer of the committee. During the months of May, June, and July, Mr. R. K. Sheppard, of the third-year class in Chemical Engineering, was in charge of the exhibit. During the last three months of the Fair, Mr. Sheppard's place was taken by Mr. W. S. Hutchinson, of the class of 1892, who had during the year served as assistant to the Secretary. In connection with the exhibit at Chicago the President prepared a pamphlet, descriptive of the work and history of the Institute, illustrated by a considerable number of half-tone prints. Mr. Andrews prepared a new edition of the list of periodicals taken at the Institute; Professor Norton and Dr. Gill, of the Chemical Department, brought out a revised and enlarged edition of publications of officers and former students of the school, begun by Professor Nichols, and brought down to 1888 by Professor Norton. The courts of the Institute were visited by vast numbers during the six months of the great Exhibition. The large majority of course simply wandered through, looking about for something curious or striking; but many hundreds of earnest students of science and technology, teachers, superintendents of schools, and others visited our exhibit for the purpose of careful and protracted examination.

In connection with our exhibit at Chicago, cordial acknowledgment should be made of assistance rendered by our alumni. The general Alumni Association raised nearly $2,500 toward the expenses of the exhibit, and also bore the entire expense of completing and publishing the list of publications by officers and students of the Institute, to which I have before alluded. The Northwestern Associa-

tion also raised a considerable sum of money, which was used in maintaining a headquarters for Institute men while in Chicago. A suite of pleasant and commodious rooms, at the corner of Michigan Avenue and Thirteenth Street, was fitted up for this purpose, and contributed much to the pleasure and convenience of our graduates and students visiting the great Exposition.

Since my last Annual Report, two highly esteemed members of the Corporation have died, — Mr. Ames and Mr. Dresser. Mr. Ames was elected to the Corporation in March, 1885. He invariably showed a high appreciation of the work of the Institute, and a cheerful readiness to assist in its development. No appeal was ever made to him in behalf of its finances which was not responded to at once with practical liberality and with cordial expressions of good-will. Mr. Dresser entered the Corporation only in June, 1891; but from the very foundation of the school he had been one of its most active and zealous friends, and a leading member of the Society of Arts. For many years he was chairman of the Executive Committee of the Society.

TREASURER'S REPORT.

STATEMENT OF THE TREASURER.

The Treasurer submits the annual statement of the financial affairs of the Institute for the year ending Sept. 30, 1893 : —

The year has been an unusual one both as regards the amounts received and the amounts expended. Two large and important purchases of real estate have been made, the one on Trinity Place and the other on Clarendon Street. The land thus bought adjoined the land already owned and used by the Institute for its Mechanical and Civil Engineering and its Architectural departments. As a result of these purchases, the Institute has been forced to burden itself with a debt of two hundred thousand dollars.* There has also been an expenditure for current expenses very largely in excess of income, resulting in a deficit of nearly thirty-three thousand dollars. This is due in part to expenses which may fairly be called exceptional and in part to the natural growth in expenses as the Institute grows. The exhibit at the World's Fair involved an outlay of more than eight thousand dollars. Last year the Institute received from the State Endowment Fund the accumulated appropriations of four years, amounting to twenty-two thousand dollars. This year the amount received is only a little more than six thousand dollars. There has been a considerable amount of interest to pay on the money borrowed for the purchase of real estate, and there has been a falling off in income due to the maturing of bonds paying a high rate of interest and the reinvestment of the proceeds at necessarily lower rates.

To offset the discouraging features of the account, there have been unusually large bequests and gifts made to the Institute during the past year, as follows : —

From the estate of the late Mrs. Martha Ann Edwards, property of the value of over ninety-eight thousand dollars.

From the subscription of 1892, the sum of eighty thousand five hundred dollars, leaving about thirty thousand dollars still to be received.

From the estate of the late T. O. H. P. Burnham, twenty thousand dollars, from which, in accordance with Mr. Burnham's wish, about fourteen thousand dollars have been devoted to the purchase of the great Emery testing-machine.

From Mrs. Susan E. Covill, of Springfield, five thousand dollars, to be held as the Wm. F. Huntington Scholarship Fund, the preference being given to students in Civil Engineering.

From Miss Susan Upham, one thousand dollars for scholarship purposes.

From the Alumni of the Institute, two thousand dollars, to be applied towards the expenses of the Institute's exhibit at the World's Fair. The Alumni have also added five hundred dollars to the Wm. B. Rogers Fund.

From Mrs. Wm. B. Rogers, for periodicals, two hundred dollars.

From Samuel Cabot, Esq., for special work in connection with the Chemical Department, one hundred dollars.

From the Civil Engineers' Society, for the purchase of books, seventy-five dollars.

The net result of the year is an increase, amounting to about one hundred and seventy-six thousand dollars, in the property of the Institute.

* A portion of this real estate has now been leased to the Boston Art Student Association.

GEORGE WIGGLESWORTH, TREASURER, *in account with*

GENERAL STATEMENT OF RECEIPTS AND DISBURSEMENTS

Dr.

Cash balance Sept. 30, 1892		$5,006.95
From Augustus Lowell for Lowell Courses	$4,800.00	
" " " " C. Kastner's salary	2,500.00	
" " " " Lowell School of Design	867.82	8,167.82
RECEIPTS FOR CURRENT EXPENSES.		
Income of funds for salaries	$4,380.00	
" " " " scholarships (students' fees)	3,875.00	
" " " " Joy "	200.00	
" " " " Swett "	400.00	
" " " " Library	250.00	
" " " " general purposes	10,389.12	
" " Rogers Memorial Fund	12,975.61	
Students' fees	194,775.00	
State Agricultural Fund	4,785.76	
State Endowment Fund	6,333.34	
Laboratory supplies and breakages	5,470.16	
Rents, per Table (page 12)	8,293.26	
Gifts	3,375.00	
Contributed by former M. I. T. Students for expenses at World's Columbian Exposition	2,000.00	
Interest	1,951.11	
Pope Fund for Highway Engineering, used	868.88	
Letter-Box Fund $162.00, used of 1892, $13.00	175.00	
Boston University	1,150.00	
Sale printed Lecture Notes	2,413.96	
Profit and Loss, expenses more than income	32,816.75	296,877.95
BEQUESTS FOR SPECIAL PURPOSES, ETC.		
Income James Savage Fund, not used	$602.30	
" James H. Mirrlees Fund, " "	7.98	
" William Barton Rogers Fund, " "	30.55	
" Elisha Thacher Loring Fund, " "	63.30	
" Richard Perkins Fund, " "	128.78	
" Charlotte B. Richardson Fund, " "	1,618.31	
" Charles Lewis Flint Fund, " "	59.71	
" Pope Fund, " "	331.12	
William F. Huntington Fund (income " ")	5,208.33	
Susan Upham Fund (" " ")	1,037.50	
W. B. Rogers Fund (additional)	500.00	
Scholarship Fund	500.00	10,087.88
GIFTS AND BEQUESTS FOR GENERAL PURPOSES.		
Martha Ann Edwards Legacy	$98,452.89	
Subscriptions of 1892 (additional)	80,500.00	
T. O. H. P. Burnham Legacy	20,000.00	198,952.89
SECURITIES SOLD OR PAID. GENERAL FUND: 15,000 Bur. & Mo. River R. R. L. G. 7s.		15,000.00
SECURITIES SOLD OR PAID. W. B. ROGERS M. F. 20,000 Mo. V. Blair R. & B. Co. 6s.		20,000.00
SUNDRIES.		
Income General Funds credited to Advance Bond Premium Account	$363.19	
Income Wm. B. Rogers Mem. Fund credited to Advance Bond Premium Account	400.00	
Students' Deposits	100.00	
Rent reserved to pay annuity under M. A. Edwards Legacy	250.00	
Students' Notes paid	105.00	
Borrowed on Mortgage Notes	200,000.00	201,218.19
		$755,311.68

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

FOR THE YEAR ENDING SEPTEMBER 30, 1893.

Cr.

Paid for Lowell Courses	$4,800.00	
" " Charles Kastner's salary	2,500.00	
" " Expense Lowell School of Design	867.82	
		$8,167.82
EXPENSES.		
Salaries, per Table (page 12)	$188,373.13	
" paid from the Pope Fund	600.00	
Supplies " " " " "	268.88	
Scholarships paid from Swett Fund	400.00	
Repairs, per Table (page 12)	12,813.70	
General Expense, per Table (page 13)	16,158.89	
Fuel	11,886.10	
Water	1,450.80	
Gas	2,120.84	
Printing and Advertising	4,557.85	
" Lecture Notes	3,074.18	
" Annual Catalogue	1,956.70	
Rents paid Boston & Albany R. R. Co.	180.00	
" " Natural History Society	200.00	
Laboratory Supplies and Libraries, per Table (page 12)	30,513.44	
Society of Arts	946.57	
World's Columbian Exposition	8,231.56	
Interest, 5 per cent on funds not in stocks and bonds	7,384.19	
Interest paid A. Lowell, Trustee	1,000.00	
" " on Mortgage Notes	4.761.12	
		296,877.95

SECURITIES BOUGHT OR RECEIVED AS LEGACIES. GENERAL ACCOUNT.			
$2,000	Chi. Bur. & Northern R. R. 5s	$2,040.00	
2,000	Atchison Topeka & Santa Fé 4s	1,605.00	
6,000	West End Street R'w'y 5s 1902	6,240.00	
112	Sh. Morris & Essex R. R.	8,540 00	
83	" Pennsylvania Coal Co.	11,910.50	
65	" Pittsburg, Fort Wayne & C. R.R.	9,880.00	
House No. 34 Commonwealth Ave		30,000.00	
			70,215.50
SECURITIES BOUGHT FOR, OR TRANSFERRED TO, WM. B. ROGERS MEMORIAL FUND.			
$2,000	Kansas City Belt R. R. 6s.	$2,160.00	
20,000	Chicago, Burlington & Quincy R. R., Conv. 5s	18,820.00	
			20,980.00
SUNDRIES.			
Gymnasium Building (additional)		$225.00	
Architects' Building (additional)		22,925.78	
Annuity under M. A. Edwards Legacy		250.00	
Letter Box Fund 1892, used		13.00	
Emery Testing Machine		13,853.27	
Lot No. 2 Trinity Place		137,241.60	
Clarendon Street Land and Building		139,702.00	
Profit and Loss, per contra. (See page 4)		32,816.75	
			347,027.40
Cash balance, Sept. 30, 1893			12,043.01
			$755,311.68

The following account exhibits the property held by the Institute, as per Treasurer's books, Sept. 30, 1893:—

INVESTMENT OF THE W. B. ROGERS MEMORIAL FUND.

$50,000.00	Saginaw & Western R. R. 6s	1913	$50,000.00	
30,000.00	Burlington & Mo. River R. R. 4s	1910	25,787.50	
27,000.00	Kansas City Belt R. R. 6s	1916	27,000.00	
18,000.00	Atchison, Topeka & Santa Fé R. R. 4s (Reg'd)	1989	15,372.30	
16,000.00	Kansas City, Clinton & Springfield R. R. 5s	1925	16,000.00	
7,000.00	Omaha & Southwestern R. R. 8s	1896	7,000.00	
5,400.00	Republican Valley R. R. 6s	1919	5,400.00	
4,000.00	Cin., Ind., St. Louis & Chicago R. R. 6s	1920	4,000.00	
2,000.00	Ottawa, Oswego & Fox River R. R. 8s	1900	2,000.00	
2,000.00	New York & New England R. R. First 6s	1905	2,000.00	
2,000.00	Kansas City, Fort Scott & Gulf R. R. 7s	1908	2,000.00	
2,000.00	Kansas City, Memphis & Birmingham R. R. 5s	1927	1,905.00	
250.00	" " " Coupon Note	1901	250.00	
1,000.00	Lincoln & Northwestern R. R. 7s	1910	1,000.00	
1,000.00	Atchison & Nebraska R. R. 7s	1908	1,000.00	
7,000.00	Chicago, Burlington & Quincy R. R. 7s	1903	7,000.00	
42,000.00	" " " " Conv. 5s	1903	40,820.00	
35,000.00	Fort Street Union Depot 4½s	1941	34,825.00	
	Advances to Bond Premium account		7,293.91	
	Bonds			$250,653.71

INVESTMENT OF THE JOY SCHOLARSHIP FUND.

Massachusetts Hospital Life Insurance Co	$5,000.00	
Deposits in Savings Banks	3,555.83	
		8,555.83

INVESTMENT, SWETT SCHOLARSHIP FUND.

Massachusetts Hospital Life Insurance Co.	10,000.00

INVESTMENTS, GENERAL ACCOUNT.

$50,000.00	Atchison, Topeka & Santa Fé R. R. 6s	1893	$50,000.00	
2,000.00	" " " " 4s	1989	1,605.00	
18,000.00	Bur. & Mo. River (Neb.) R. R. 6s, non-exempt	1918	18,000.00	
6,000.00	Chicago, Burlington & Quincy R. R. 4s	1922	5,100.00	
3,000.00	Milwaukee & St. Paul R. R. 7 3-10	1898	3,000.00	
4,000.00	Chicago, Burlington & Northern R. R. 5s	1926	4,000.00	
2,000.00	Kansas City, Fort Scott & Gulf R. R. 7s	1908	2,000.00	
1,000.00	International & Great Northern R. R. 6s	1919	1,000.00	
1,000.00	Union Pacific R. R. 6s	1898	1,000.00	
13,000.00	New York & New England R. R. First 6s	1905	13,000.00	
3,000.00	Hannibal & St. Joseph R. R. 6s	1911	3,000.00	
25,000.00	Eastern R. R. of Minnesota 5s	1908	25,000.00	
15,000.00	Chicago, Burlington & Quincy R. R. Conv. 5s	1903	15,000.00	
6,000.00	West End Street Ry. 5s	1902	6,000.00	
	Advances to Bond Premium account		2,100.00	
	Bonds			149,805.00
	Amount carried up			$419,014.54

Amount brought up				$419,014.54

STOCKS.

SHARES.				
148 Boston & Albany R. R.	par	100	$29,933.00	
12 Cocheco Manufacturing Co.	"	500	6,000.00	
55 Old Boston National Bank	"	100	5,510.50	
50 Hamilton Woollen Co.	"	100	5,000.00	
194 Morris & Essex R. R.	"	50	14,690.00	
27 Essex Co.	"	50	4,050.00	
158 Pennsylvania Coal Co.	"	50	23,160.50	
35 Everett Mills	"	100	3,150.00	
40 New York & Harlem R. R.	"	50	5,000.00	
85 Pittsburg, Fort Wayne & C. R. R.	"	100	12,880.00	
15 Consolidated Gas Co., New York	"	100	1,447.50	
				110,821.50

REAL ESTATE.

Rogers Building		$315,726.88	
Walker Building		190,492.44	
Land on Garrison Street . . .	$50,840.00		
Workshops " "	52,416.49		
		103,256.49	
Land on Trinity Place	$76,315.69		
Engineering B'ld'g, Trinity Place	106,616.87		
		182,932.56	
Gymnasium Building		7,967.85	
Architects' Building		57,857.10	
Lot No. 2 Trinity Place		137,241.60	
Clarendon St. Land and Building		139,702.00	
House No. 34 Commonwealth Ave. . . .		30,000.00	
			1,165,176.92
Equipment, Engineering Building		$16,555.24	
" Workshops		20,628.56	
			37,183.80

SUNDRIES.

Notes Receivable	$1,500.00	
Emery Testing Machine	13,853.27	
Students' Notes	2,300.00	
Cash Balance, Sept. 30, 1893	12,043.01	
		29,696.28
		$1,761,893.04

The foregoing Property represents the following Funds and Balances, and is answerable for the same.

The Income of the following is used for the general purposes of the Institute: —

William Barton Rogers Memorial Fund	$250,225.00	
Richard Perkins Fund	50,000.00	
George Bucknam Dorr Fund	49,573.47	
Martha Ann Edwards "	30,000.00	
Nathaniel C. Nash "	10,000.00	
Sidney Bartlett "	10,000.00	
Robert E. Rogers "	7,680.77	
Albion K. P. Welch "	5,000.00	
Stanton Blake "	5,000.00	
McGregor "	2,500.00	
General Institute "	36,028.00	
		$456,007.24

The Income of the following is used towards paying salaries: —

Nathaniel Thayer, for Professorship of Physics,	$25,000.00	
Jas. Hayward, for Professorship of Engineering,	18,800.00	
William P. Mason, " Geology	18,800.00	
Henry B. Rogers, for General Salaries	25,000.00	
		87,600.00

SCHOLARSHIP TRUSTS.

Richard Perkins Fund	$52,704.24	
James Savage Fund	12,648.26	
Mrs. Susan H. Swett Fund	10,182.95	
William Barton Rogers Fund	9,388.33	
Joy Fund	8,555.83	
Elisha Thacher Loring Fund	5,329.39	
Charles Lewis Flint Fund	5,253.93	
Thomas Sherwin Fund	5,000.00	
Farnsworth Fund	5,000.00	
James H. Mirrlees Fund	2,667.61	
William F. Huntington Fund	5,208.33	
Susan Upham Fund	1,037.50	
Scholarship Fund	500.00	
		123,476.37

OTHER TRUSTS.

Charlotte Billings Richardson, Industrial Chemistry Fund,	33,984.56
Charles Lewis Flint, Library Fund	5,000.00
Albert A. Pope, Street Building and Highway Engineering Fund, balance	1,046.13
Letter Box Fund, balance	196.37

MISCELLANEOUS.

Notes Payable	$220,000.00	
Students' Deposits	500.00	
Subscription of 1887	123,500.00	
Subscription of 1892	96,750.00	
Martha Ann Edwards Legacy, 1893	98,452.89	
T. O. H. P. Burnham Legacy, 1893	20,000.00	
M. I. T. Stock Account	495,379.48	1,054,582.37
		$1,761,893.04

Comparative Statement of Funds, etc.

	Sept. 30, 1892.	Sept. 30, 1893.
ts for general purposes	$456,007.24	$456,007.24
" Salaries	87,600.00	87,600.00
" Scholarships	115,337.92	123,476.37
" Library	5,000.00	5,000.00
lotte B. Richardson Ind. Chem. Fund	32,366.25	33,984.56
rt A. Pope Street Building and High- way Engineering Fund	715.01	1,046.13
:r Box Fund	209.37	196.37
s Payable	20,000.00	220,000.00
ents' Deposits	400.00	500.00
cription of 1887	123,500.00	123,500.00
" " 1892	16,250.00	96,750.00
ha Ann Edwards Legacy		98,452.89
. H. P. Burnham Legacy		20,000.00
. T. Stock Account	528,196.23	495,379.48
	$1,385,582.02	$1,761,893.04
ase	376,311.02	
nsisting of: —		
lotte B. Richardson Fund Income	1,618.31	
larship Funds, not used	1,138.45	
cription of 1892, increase	80,500.00	
. Pope Fund, increase	331.12	
B. Rogers Fund, increase	500.00	
ha Ann Edwards Legacy	98,452.89	
. H. P. Burnham Legacy	20,000.00	
F. Huntington Fund	5,000.00	
n Upham Fund	1,000.00	
larship Fund	500.00	
ents' Deposits, increase	100.00	
s Payable	200,000.00	
		409,140.77
Loss. Expenses more than Income	$32,816.75	
on Letter Box Fund	13.00	
		32,829.75
		$376,311.02

...e from Railroad Bonds . . $13,375.61

$13,375.61

400.00

$13,375.61

...rison Fund ...
...ds, not used .
...of 1892, increase
...and, increase .
...rs Fund, increase
...dwards Legacy
...urnham Legacy
...ington Fund .
... Fund . . . .
...und . . . .
...osits, increase
. . . . .

...penses more ...
...Box Fund .

INCOME FROM GENERAL INVESTMENTS, AND APPLICATION THEREOF.

Applied to Salaries	$4,380.00	From Dividends, Old Boston National Bank	$247.50
" " Scholarships	3,875.00	" State Tax returned, Old Boston National Bank	82.18
" " Library	250.00	" Railroad Bonds	9,568.20
" " General Purposes	10,389.12	" Dividends, Pittsburg, Ft. W. & C. R. R. Stock	140.00
" " Increase of Funds	2,736.76	" Dividends, Pennsylvania Coal Co.	1,382.00
" " Advances to Bond Premiums	363.19	" " Everett Mills	210.00
		" " Essex Co.	162.00
		" " Cocheco Mfg. Co.	240.00
		" " Consolidated Gas Co., N. Y.	105.00
		" " New York and Harlem R. R.	210.00
		" " Hamilton Woollen Mills	300.00
		" " Morris & Essex R. R.	483.00
		" " Boston & Albany R. R.	1,480.00
		" Interest allowed on Funds not in Bonds and Stocks @ 5%	7,384.19
	$21,994.07		$21,994.07

INCOME FROM WILLIAM BARTON ROGERS MEMORIAL FUND, AND APPLICATION THEREOF.

Paid Massachusetts Institute of Technology 5%		Received Income from Railroad Bonds . .	$13,375.61
on Amount of Fund ($250,225.00) + 464.36	$12,975.61		
Credited to Advances Bond Premiums . . .	400.00		
	$13,375.61		$13,375.61

DETAILS OF SOME ITEMS IN TREASURER'S CASH ACCOUNT.

Rents.

Huntington Hall, for Lowell Lectures	$3,500.00	
Lowell School of Design	1,800.00	
Chauncy Hall School, for Gymnasium	500.00	
State Board of Health, for use of Laboratories	1,087.50	
Boston Water Works, use of Laboratory	200.00	
"Rink" Building, Clarendon Street	657.00	
34 Commonwealth Avenue $550.00 less $250.00 reserved for Annuity under Martha Ann Edwards Legacy	300.00	
Use of Lecture Rooms and Gymnasium	248.76	
		$8,293.26

Department Supplies.

Chemistry	$9,060.48	
Physics	5,345.62	
Mining	1,520.58	
Mechanical Engineering	2,353.04	
Naval Architecture	248.92	
Applied Mechanics	1,579.84	
Civil Engineering	2,761.32	
Biology	1,136.97	
Geology	830.00	
Architecture	963.90	
Drawing	46.03	
Mathematics	352.70	
English	903.17	
Workshops	1,881.08	
Modern Languages	264.48	
Periodicals	1,265.31	
		$30,513.44

Salaries.

Instruction	$155,141.94	
Administration	16,916.66	
Labor	16,314.53	
		$188,373.13

Repairs.

Department Improvements: —		
Physics	$1,348.43	
Chemistry	1,247.34	
Workshops	469.03	
Mechanical Engineering	427.59	
Geology	250.04	
Architecture	138.07	
Drawing	135.50	
Amount carried forward	$4,016.00	

Amount brought forward		$4,016.00	
Modern Language		134.37	
Mining		79.66	
Civil Engineering		63.99	
Applied Mechanics		63.26	
Biology		41.64	
English		38.51	
Mathematics		23.25	
			$4,460.68
Walker Building			1,499.37
Rogers "			1,370.46
Gymnasium Building			600.14
Engineering "			297.05
Architects' "			112.17
Steam Fitting			598.75
Painting brick walls, columns, etc. *white*, Engineering Building			551.00
Blackboards			492.83
Boiler and Boiler-Room Machinery			592.31
Plumbing			267.64
Covering Pipes in Mech. Eng. Build'g Lab.			206.25
Ventilation Huntington Hall (see Gen. Ex.)			204.06
Lunch Room			156.19
President's, Secretary's, and Bursar's Offices			93.82
Lowell School of Design			93.80
World's Columbian Exposition (labor)			55.67
Sundries			1,161.51
			$12,813.70

General Expenses.

Fire Insurance		$2,012.95
Stationery and Office Supplies		1,565.93
Postage		1,383.73
Furniture		1,272.92
Paints, Varnish, etc		869.04
Entrance Examinations		766.95
Gymnasium Supplies, etc.		713.70
Express Charges, Teaming, etc.		692.08
Architects' Building		682.85
Janitor's Supplies: —		
Brushes, Pails, Soap, etc.		630.52
Diplomas, Commissions, and Expense of Drills		536.37
Ventilation, Huntington Hall (see Repairs)		523.49
Legal Fees		509.94
Examination Books		483.60
Washing		477.63
New Engine, ventilation Walker Building		467.59
Engine Room Supplies: —		
Oil	$312.00	
Cotton Waste	42.57	
Sundries	88.92	
		443.49
Amount carried forward		$14,032.78

Amount brought forward		$14,032.78	
Electric Lighting: —			
Power Furnished	$231.40		
Wiring, etc.	163.29		
		394.69	
Books and Supplies for General Library . . .		316.23	
Window Glass		254.10	
Lowell School of Design		250.28	
Telephone and Telegraph Charges		174.17	
Ice		146.77	
Tablets, Mining Department		140.00	
Eco. Magneto Clock Co. (Watchman's) . . .		113.00	
Window Shades		106.50	
Towelling		94.81	
Drafting, Testing, etc.		47.56	
Safe, Chemical Department		38.00	
Union Deposit Vaults		50.00	
			$16,158.89

BOSTON, Dec. 7, 1893.

An examination of the accounts of the Treasurer of the MASSACHUSETTS INSTITUTE OF TECHNOLOGY for the year ending Sept. 30, 893, has been made, and they are found to be correctly cast, and ·ith proper vouchers. The ledger balances agree with the trial ·alance. We have verified the evidences of personal property held ·y the Institute.

FREDERIC W. LINCOLN,
JAMES P. TOLMAN,
CHARLES C. JACKSON,
Auditing Committee.